NOTES

ON

BUILDING CONSTRUCTION

ARRANGED TO MEET THE REQUIREMENTS OF THE SYLLABUS OF THE BOARD OF EDUCATION, SOUTH KENSINGTON

PART I.

WITH 695 ILLUSTRATIONS

New Edition, Revised and Enlarged

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BIBLIOGRAPHICAL NOTE

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PREFACE TO PART I.

THESE Notes have been prepared primarily in order to assist students preparing for the examinations in Building Construction held annually under the direction of the Board of Education, South Kensington.

It is hoped that they may be found useful by others engaged in designing or erecting buildings.

The following Syllabus of the Board of Education has been taken as a guide in the arrangement of the Notes, and in determining the subjects to be treated upon.

SYLLABUS.[1]

Subject III.—Building Construction.

A larger number of questions will be set in the examination papers than the candidate will be allowed to attempt, so that he may have some range of selection of questions which bear upon branches to which he has given special attention.

A student of this subject must be a draughtsman. He should be able to show definitely by drawings what he intends to have carried out, and he should be able, with readiness, to explain details of construction by drawings and sketches. In the several stages he will be expected to show proficiency both in finished drawing and what may be called descriptive and explanatory drawing. He should know the most usual methods of multiplying drawings and copies of quantities as practised in architects' and builders' offices. He should practise sketching approximately to scale, and paper ruled in faint squares is recommended for this purpose. It is to be noted, however, that the subject of examination is Building Construction, and not

[1] Taken from the "Syllabuses and Lists of Apparatus applicable to Schools and Classes other than Elementary," Board of Education, South Kensington. Edit. 1903.

drawing in the abstract. Certain of the questions set will require written answers only; for others, sketches to scale, on squared paper or otherwise, may suffice. The knowledge of drawing assumed includes the use of the usual drawing instruments, scales, various ways of laying down angles, applied projection (isometrical included), and perspective. In the 1903 examination and afterwards Students will be required to make an inked tracing of a portion of a drawing, the lines being very uniform and continuous, and fairly thick, such as would be useful for a blue print.

Questions may be put which will specially test the candidate's neatness and accuracy in inking in—curves and straight lines meeting curves, etc. The student is recommended to practise neat plain lettering and figuring.

Questions will also be set to test the candidate's knowledge of the tools, plant, and appliances used in building.

Tables will be supplied to candidates in Honours to assist them in calculation. Slide Rules may be used by candidates in all the stages.

Compulsory questions may be set at the examination.

MEMORANDUM UPON THE PREPARATION OF DRAWINGS BY STUDENTS.

Drawings to scale should be prepared in such a way as to give full information and exact guidance to the workmen who may have to use them, neither more nor less. All drawings, lettering, and numerals should be neat and clear; they should not be what is called "ornamental." Either italics or engrossing letters should be adopted.

There is no difference between the purpose of descriptive drawings for buildings and of those for machines and other constructive works, but there may be some difference in office practice in their preparation.

For good work architects should, in descriptive drawings, follow the modern method of machine draughtsmen. This is to produce an accurate, well-finished tracing from which any number of prints may be taken. "Blue prints," showing white lines on a blue ground, are the most easily prepared, and serve most practical purposes. But prints on a white ground are specially suitable in some cases, as they can be coloured. Students should therefore in their classes make only pencil drawings on white paper.

Students of architectural construction need to practise freehand sketching. This they may do in connection with their work in class, which should largely consist of making dimensioned sketches and drawings from actual details of building construction. Little or no drawing from mere copies should be done.

STAGE 1.

The candidate should know: How a pull or a push of so many pounds may be represented in direction and magnitude by a straight

line, and how three forces in one plane in equilibrium, at a point, may be represented to scale and are parallel and equal to the sides of a triangle; the weights of water and iron, and approximately of other materials used in building; the meaning of stress per square inch (or other unit of area); roughly, the safe loads for common materials; about mortars, quality of good sand, Portland cement, limes; about slates and roofing tiles, and modes of fastening; about concreting in floors, roofs, walls, etc., plain floor tiling, spacing of joists, rafters, etc.; plain carpentry and joinery, trimming joists and rafters, usual scantlings of timber, proportions of doors, windows, floors, skirtings, simple trimmings round doors and windows; elementary ventilation and warming; bonds of brickwork; varieties of rubble masonry; plain plastering; plain painting and glazing; easy plumber's work; ironwork, locks, hinges, fastenings, grates, rainwater pipes and gutters, etc.; elementary drainage, connections with sewers and cesspools.

The bulk of the questions will have to do with elementary buildings—say labourers' cottages and artisans' dwellings.

Questions will be set to test the powers of direct observation of the student, and he is recommended to miss no opportunity he may have of inspecting buildings in process of construction.

STAGE 2.

The questions set in this stage shall be designed to test advanced knowledge of the subjects enumerated for Stage 1. The bulk of the questions will apply to buildings up to and inclusive of town houses of £100 valuation, country villas, ordinary shops, and medium-sized warehouses.

The student should know: How to draw diagrams of stresses for roof trusses and simple braced girders with simple gravitation loads; how trusses of wood and of iron (or steel) are put together (spans up to 40 feet); the use of rolled joists, weights and strengths of stock sizes, the bearing of beams on walls; connection of woodwork to walls; to find the bending moment at any part of a beam under any system of gravitation loading (beam supported at both ends); what is meant by moment of inertia of a cross section; Young's modulus; combinations of iron (or steel) and Portland cement concrete, concrete roofs fireproof construction; to test Portland cement; varieties of timber, sources and characteristics; well-known building stones, bricks, and building materials generally; how to take rough quantities for estimating.

Questions will be set in: Excavation for foundations, sewers, etc.; timbering, piling, concreting, framing, nature of soil, etc.; damp courses; exclusion of vermin; dampness of site; connection of walls with ground, etc.; purpose-made brickwork, terra-cotta, artificial stone, etc.; stone cutting, various dressings for quoins and ashlar, stone stairs, etc.; slating sizes and qualities of slate, hips, valleys, fancy slating, creasing, shelves, cisterns, sinks, etc.; advanced

carpentry and joinery, panelling, stair building, etc.; casement and French windows, wainscotings, window trimmings, etc.; asphalting, sound deadening, ventilation, hot-water supply, heating, gas and electric supply, water supply, lightning conductors, preservation of iron, timber, etc.; lead, etc., lights in wood frames and in stone opes; various kinds of glass and glazing; ranges, grates, mantels, fastenings of all kinds; furniture of doors, etc., bells; painter's work of all kinds; advanced plumber's work, soil pipes, ventilation pipes, connections with sewers, traps inspection chambers, water-closets, baths, sinks, flashings, flats, gutters, valleys, etc.; scaffolding; shoring and strutting; effects of wind and rain on buildings, etc., etc.

STAGE 3.

This Course will include buildings of all kinds and sizes. The student will be expected to show that he can practically apply principles of physics (mechanics, chemistry, etc.) in building construction. He should be able to design roof trusses and beams of every kind; to draw stress diagrams of trusses under every kind of loading; to calculate the thrust of arches and provide for every kind of stress at every part of large buildings; to understand the method of taking quantities, and he should know something of relative and approximate prices of work and materials; to explain in a rational way the mode of manufacture of important building materials—cement-making, brick-making, quarrying, etc.; he should be able to describe tests for every kind of important building material; he should be able to answer questions showing an intimate knowledge of all the matters enumerated for the lower grades.

HONOURS.

No candidate will be credited with a success in Honours who has not obtained a previous success in Stage 3 (or Honours, Part I.).

This Course will include questions on the history of architecture. The candidate will be required to show by sketches and drawings that he has an accurate knowledge of notable examples of architecture. It will also include the subject of specifications.

The examiner will have in mind in setting the questions the actual practice of architects in designing buildings, and in their management of assistants and clerks of works to ensure that their orders will be properly carried out, the dealing with contractors, and also the actual carrying out of works under direct management. Candidates will be asked to make sketch designs and give instructions to draughtsmen for careful scale drawings and specifications. The questions may deal with any part of the subject and with any kind of building whatever.

Those candidates whose answering of the paper is sufficiently satisfactory will be summoned to South Kensington for a practical examination. This further examination will be held on one or more

days—the time will not exceed seven hours each day. Candidates will be asked to design a building suitable for a definite purpose, and they shall be required to give such plans, elevations, and sections, and such details and notes for a specification, as shall be required by the examiner. An estimate of cost will also be required.

Candidates must provide T-squares, set squares, drawing instruments, ink, and colours. Drawing-paper and drawing-boards will be provided by the Board of Education.

No candidate can be classed in Honours who is not successful in the practical examination.

In these Notes the subjects of the above Syllabus are divided as follows :—

Parts I., II., and IV. treat on the majority of the subjects laid down as necessary for the examination in Stages 1 and 2.

Part III. furnishes full particulars regarding the materials used in building and engineering works, including information on this subject that is required for Stage 3.

Part IV. explains and illustrates the problems involved in the theory of construction of buildings and their application in practice, and will contain all that a student can require to prepare himself for the examinations on this subject for Stage 3. The history and styles of architecture, the preparation of specifications and quantities, the relative and approximate prices of labour and materials, and the art of designing buildings from given conditions, must be studied in works specially devoted to those subjects.

In order to make these Notes useful to students throughout the country, many of the Scotch and Irish technical terms, where they differ from those in ordinary use in England, have been given in footnotes.

REVISED AND ENLARGED EDITION, 1904.

The following are the principal additions or alterations that have been made in this edition :—

Those subjects which in former Editions were treated partly in Part I. and partly in Part II. have in this Edition been brought together in consecutive order in one volume, so that the subjects referred to are complete within the scope of this Part. They are as follows :— Walling and Arches, Brickwork, Masonry, Carpentry (under the various headings of Joints and Fastenings, Floors, Beams, Partitions, Centres, and Timber Roofs), Roof Coverings (including Slating and Plumbing), Constructional Ironwork (including Cast and Riveted Girders, Riveting, and Steel or Iron Roofs).

In a similar manner the subject of Joinery will now be found treated consecutively in Part II., which also contains entirely new Chapters on the important subjects of Drainage and Sanitation, Heating and Ventilation, and Electric and Gas Lighting (including also Bells and Signals, Telephones, and Lightning Conductors).

NOTES ON BUILDING CONSTRUCTION.

Note to Part I.

In considering the subject of Building Construction, the most natural and convenient course would, perhaps, be first to describe the materials in use for building, and then to explain the forms and methods in which they are used.

The description of materials has, however, been left for Part III., and it is hoped that the student will find that the very slight general knowledge of building materials which he must be assumed to possess, will enable him to understand all that is brought before him in this Part.

The writer of these Notes has endeavoured as far as possible to acknowledge his indebtedness, wherever he has taken information or illustrations from any published works. It has been impracticable to do this in every case, and it would be difficult to give a long list of all the authorities consulted.

Special mention should, however, be made of the works named below, whence much assistance has been derived, and to which the student may be referred for more extensive information regarding the subjects herein treated upon.

Adam's Designing Wrought and Cast Iron Structures.
Dempsey's Builder's Guide.
Gwilt's Encyclopædia of Architecture.
Hurst's Architectural Surveyor's Hand-Book.
Laxton's Examples of Building Construction.
Matheson's Works in Iron.
Molesworth's Pocketbook of Engineering Formulæ.
Newland's Carpenter's and Joiner's Assistant.

Nicholson's Works.
Pasley's Practical Architecture (Brickwork).
Rankine's Civil Engineering.
Reed on Iron Shipbuilding.
Seddon's Builder's Work.
Tredgold's Carpentry (1870 edition); also a new, valuable, and greatly extended edition by Mr. Hurst, C.E.
Unwin's Wrought-Iron Bridges and Roofs.
Wray's Application of Theory to the Practice of Construction (revised by Seddon).
The Professional Journals.

Caution.—Some of the drawings, which appear to be isometrical projections, must not be measured to scale, as they are purposely distorted in order to bring important points into view.

CONTENTS OF PART I.

CHAPTER III.

MASONRY.

CHAPTER IV.

BRICKWORK AND MASONRY—*Continued from Chapters II. and III.*

CHAPTER XI.

CARPENTRY—(*Continued*).—TIMBER ROOFS—(*Continued from Chapter X.*).

CHAPTER XII.

ROOF COVERINGS.

CHAPTER XIII.

SLATING.

CHAPTER XIV.

PLUMBERS' WORK.

CHAPTER XV.

STEEL AND IRON GIRDERS.

CHAPTER XVI.

RIVETING.

CHAPTER XVII.

STEEL OR IRON ROOFS.

CHAPTER XVIII.

STEEL OR IRON ROOFS.—*Continued.*

CHAPTER I.

WALLING AND ARCHES.

WALLS.

General Remarks.—Walls[1] are required as boundaries, to retain earth or water; or, in buildings, to support the roof and floors, and to keep out the weather.

They are generally built either of brick or stone, and will be considered more in detail under the heads of "Brickwork" and "Masonry" respectively. The following points, however, should be attended to in walls of every description:—

The whole of the walling of a building should be carried up simultaneously; no part should be allowed to rise more than about 3 feet above the rest,[2] otherwise the portion first built will settle down and come to its bearings before the other is attached to it, and then the settlement which takes place in the newer portion will cause a rupture, and cracks will appear in the structure. If it should be necessary to carry up one part of a wall before the other, the end of the portion first built should be "racked back"—that is, left in steps, each course projecting farther than the one above it.

Work should not be hurried unless done in cement, but given time to take its bearings gradually.

New work built in mortar should never be bonded to old, until the former has quite settled down. Then bonds may be inserted if required.

As a rule, it is better that the new work should butt against the old, either with a straight joint visible on the face, or let into a chase,[3] so that the straight joint may not show; but if it be necessary to bond them together, the new work should be built in a quick-setting cement, and each part of it allowed to harden before being weighted.

Even after walls are completed, they are likely to crack if unequally loaded.

The walls of a building are as a rule vertical, in which case each course should be laid level in every direction. In inclined or "battering" walls the courses should be at right angles to the pressure upon them.

Bond[4] is an arrangement of bricks or stones placed in juxta-

[1] Sc. *Dykes.*

[2] A scaffold height is sometimes made the limit.

[3] Sometimes called a *slip joint.*

[4] Sc. *Band.*

position, so as to prevent the vertical joint between any two bricks or stones falling into a continuous straight line with that between any other two.

This is called "breaking joint," and when it is not properly carried out—that is, when two or more joints do fall into the same line, as at *x y*—they form what is called a *straight joint*.

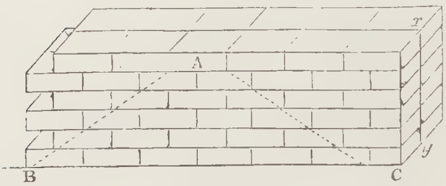


Fig. 1.

Straight joints split up and weaken the part of the wall in which they occur, and should therefore be avoided.

A good bond breaks the vertical joints both in the length and thickness of the wall, giving the bricks or stones a good lap over one another in both directions, so as to afford as much hold as possible between the different parts of the wall.

A further effect of the bond is to distribute the pressure which comes upon each brick over a large number of bricks below it. Thus in Fig. 1 there is a proper bond among the bricks forming the face of the wall, and the pressure upon the brick A is communicated to every brick within the triangle A B C.

A defective bond, either in brickwork or masonry, may look very well upon the face, as in Fig. 1, where the bricks regularly break joint vertically, but in which there is no bond whatever across the thickness of the wall, which it will be seen is really composed of two distinct slices of brickwork, each 4½ inches thick, and having no connection with one another, except that afforded by the mortar.

To avoid this defect, the bricks or stones forming a wall are not all laid in the same direction as in Fig. 1, but some are laid parallel to the length of the wall, and others at right angles to them, so that the length of one of the latter overlaps the width of two below it.

Headers[1] are bricks or stones whose lengths lie across the thickness of the wall, the ends (or "heads") of those in thin walls, or in the outsides of thick walls, being visible on the face and back.

Stretchers[1] are bricks or stones which lie parallel to the length of the wall, those in the exterior of the work showing one side in the face of the wall.

Precautions in building.—It is most important that the construction of a wall should be uniform throughout, or that care should be taken, by using

[1] Some consider these names as peculiar to brickwork; they are often used, however, in masonry, for stones placed as described. Sc. for "Header" and "Stretcher" in masonry is *Inbond* and *Outbond*.

quick-setting cement, to prevent the unequal settlement that will otherwise take place. The evils caused by neglecting these precautions will be more fully entered upon in Chapter IV.

The bricks or stones used for walling or arches should be well wetted before use, not only to remove the dust which would prevent the mortar from adhering, but also to prevent the bricks or stones from absorbing the moisture from the mortar too quickly.

In building upon old or dry work, the upper surface should be swept clean and wetted before the mortar is spread upon it to form the bed for the new work.

Neither brickwork nor masonry should ever be carried on while frost exists, or when it is likely to occur before the mortar is set.

If it is necessary to go on with the work at such a time, it must be covered up with straw or boards every night.

ARCHES.

An arch is an arrangement of blocks supported by their mutual pressure on each other (caused by their own weights), and also by the pressure of the outer blocks on the solid bodies from which the arch springs.

The blocks may be of stone or brick, cut to wedge shapes, or of moulded brick, terra-cotta, concrete, or any material which will bear compression, so that their sides radiate from the centre, except in rough work, when the sides may be left parallel, the radiation being obtained by wedge-shaped mortar joints.

The following technical terms are used in connection with arches :—

Names of Parts (see Fig. 2).—The *intrados* or *soffit* is the under surface of the arch.

The *extrados* or *back* is the outer surface.

The *face* is formed by the ends of the voussoirs, which are visible in the plane of the face of the wall or other structure in which the arch is formed.

The *springing* is the point *s* on each side from which the arch rises or "springs."

The *springing line* [1] is the line from which the arch springs—that is, the intersection of the arch with the body that supports it.

The *crown* is the highest point of the arch.

The *haunches* are the sides of the arch from the springing about half-way up towards the crown.

The *spandrils* are the spaces directly over the extrados, and under the horizontal line drawn through the crown.

[1] The line connecting the points of springing is sometimes called the *springing line.*

Abutments are the bodies supporting the arch, and from which it springs.

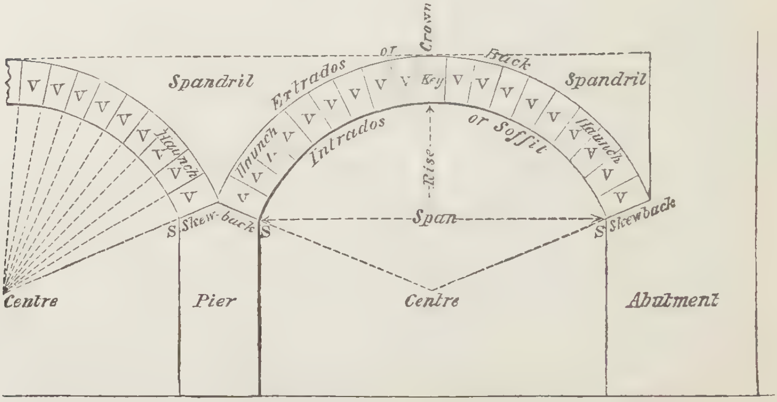


Fig. 2. *Parts of an Arch.*

This term is, however, technically applied rather to the outer support of the last of a range of arches, to distinguish it from the intermediate supports or "piers."

Piers are supports from two or more sides of which arches spring.

Jambs are the sides of piers or abutments.

Voussoirs (v v v, Fig. 2) are the blocks forming the arch, and supported by their mutual pressures.

The *key* is the centre voussoir at the crown.

Skewbacks are the upper surfaces of the abutments or piers from which an arch springs, and are so formed as to radiate from the centre.

Springers are the top stones of the pier or abutment from which the arch springs (S in Fig. 3).

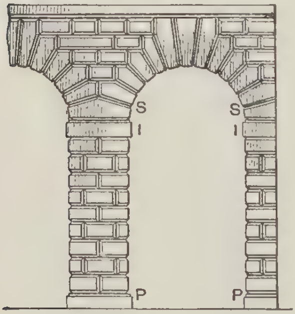


Fig. 3.

The *plinth* is the lowest stone of the pier or abutment (P in Fig. 3).

The *impost* is a projection, frequently moulded, forming the capital of the pier from which the arch springs (I in Fig. 3).

The *span* is the horizontal distance from springing to springing spanned by the arch.

The *rise* is the vertical height from the line joining the springings to the soffit at the crown.

The *length*, sometimes called the depth, is that of the line from

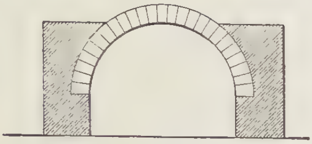


FIG. 4.
Semi-circular Arch.

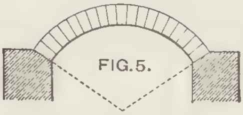


FIG. 5.
Segmental Arch.

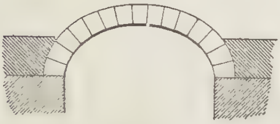


FIG. 6.
Elliptical Arch.

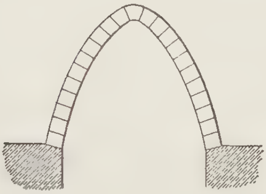


FIG. 7.
Parabolic Arch.

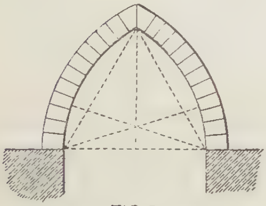


FIG. 8.
Equilateral Arch.

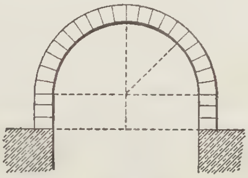


FIG. 9.
Stilted Arch.

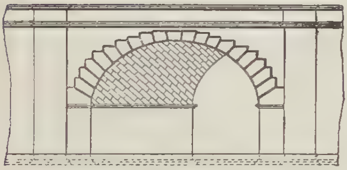


FIG. 13.
Elevation of Skew Arch.

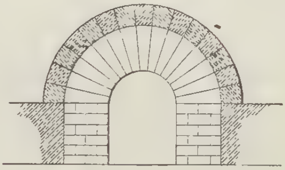


FIG. 10.
Trumpet Arch.

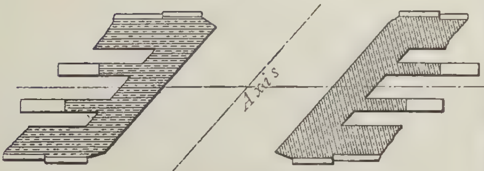


FIG. 12.
Plan of Skew Arch.

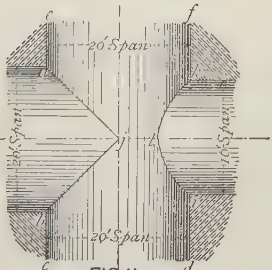


FIG. 11.
Groined Arches.
N.B. Arches all Semi-circular.

which the arch springs, or of the crown, or of any line parallel to these.

Ring courses are those parallel to the face of the arch.

String courses are those at right angles to the face and in the direction of the length.

Heading joints are those between the stones of the ring courses.

Coursing joints are those between the stones of the string courses.

Different forms of Arch (p. 5).—*A Semicircular* or *Semi-arch* is one of which the soffit line is a semicircle (Fig. 4).

A Segmental arch has an arc less than a semicircle for the curve of the soffit (Fig. 5). It is sometimes called a *Scheme arch.*

An Elliptical arch has a semi-ellipse for the curve (Fig. 6). Such an arch is necessary where there is a wide span, and but little height allowable.

A Parabolic arch has a parabolic soffit, and is used when vertical space greater than the span is required within the arch (Fig. 7).

Pointed arches are made up of circular arcs, of which two intersect so as to form a pointed crown or apex.

There are several forms of pointed arches. Fig. 8 shows one which is known as the *Equilateral arch.*

A Stilted arch (Fig. 9) is one that does not spring directly from the imposts but is raised, as it were, upon stilts for some distance above them.

A Trumpet arch (Fig. 10), sometimes called a Fluing Arch, is one in which the opening at one end is larger than that at the other, so that its interior is of a conical or trumpet shape.

A *Skew* or *Oblique arch* (Figs. 12, 13) is one of which the axis or centre line is oblique to the face.

Groined arches[1] are those which intersect one another. Fig. 11 shows a semicircular arch of 20′ span intersected by semicircular arches of 20′ and 16′ span respectively. The intersection or groin formed by the two 20-feet arches is shown by the line *a j b*, that of the 20-feet and the 16-feet arch by the line *k l i*.

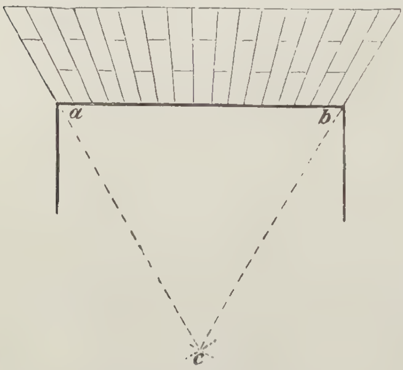


Fig. 14. *Straight Arch.*

The seven descriptions of arches last mentioned do not come within the limits of this work.

A Straight arch is shown in Fig. 14. The voussoirs radiate towards the centre *c*, found by describing an equilateral triangle upon *a b*.

This arch, though apparently flat on the soffit, is not really so, being built

[1] Or *Groined vaulting.*

with a slight "camber," or rise of about $\frac{1}{6}$ or $\frac{1}{8}$ inch to every foot of span. The extrados of the arch is sometimes given about half the camber of the soffit, in order to prevent it from being hollow when the arch settles.

There are other rules for drawing a straight arch, which, however, it is unnecessary to give in these Notes.

Camber arch is a name sometimes applied to the arch just described, or sometimes to arches with a slightly greater rise, such as 1 inch per foot of span.

Discharging arches,[1] or *Relieving arches*, are those which are turned over lintels, or over any parts of a structure which it is desired to relieve of weight, so as to relieve them from the weight of the wall above. See Figs. 99, 143, and others.

Inverted Arches are like ordinary arches, but are built with the crown downwards. They are generally semicircular or segmental in section, and are used chiefly in connection with foundations, under which head they will be further considered in Part II.

PARTS OF WALLS.

Footings[2] are projecting courses formed at the bottom of a wall so as to distribute its weight over a larger area. They will be more particularly described in connection with foundations.

Quoins are the external angles or corners of buildings. The name is also applied to the blocks (of stone or bricks) with which those angles are formed. They should, if possible, be built more strongly than the rest of the walling, and are frequently so worked as to be more conspicuous.

Salient external angles of buildings which are greater or less than right angles are termed *Squint Quoins*. Similar re-entering angles are called *Birds' Mouths*.

A Coping[3] is a course placed upon the top of a wall to prevent wet from entering and soaking into the masonry (see Fig. 128 and others).

It should, therefore, be of an impervious material, containing as few joints as possible, and should be set in hydraulic mortar or cement.

The upper surface should be "weathered"[4] (see Fig. 131) or sloped (see Fig. 129), so as to throw off the rain.

The coping should project a little over the wall on both sides; and should be "throated"[4] (see Fig. 131), so that the wet may fall clear of the wall.

[1] Sc. *Saving Arches.* [2] Sc. *Scarcements.* [3] Sc. *Cope.* [4] See Note, p. 51.

Brick and stone copings differ considerably in their construction, the details of which will be entered upon in Chap. II.

A Cornice is a large moulded or ornamental course at the top of a wall, and is of the nature of a coping. The name is applied rather to the upper member of a principal wall in a building; whereas a coping generally surmounts a detached or less important wall.

Fig. 15 shows a cornice at C, and more detailed examples will be found in Figs. 118, 147, and others.

A Blocking Course is a course of stone placed on the top of a cornice to add to its appearance, and, by its weight, to steady the cornice, and prevent its tendency to overbalance.

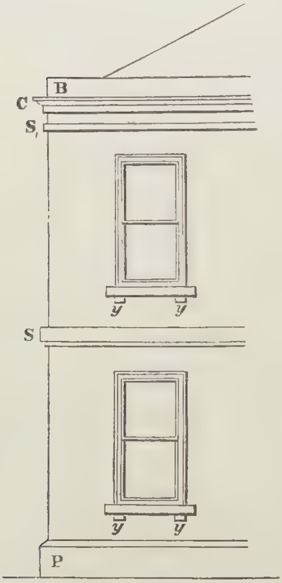


Fig. 15.

The blocking course in Fig. 15 is marked B; and sections of a similar blocking course will be found in Figs. 353, 435, etc.

The name is also sometimes applied to a thick string course.

A Parapet Wall is a low wall running along the edge of a roof gutter or high terrace, to prevent people from falling over. See Figs. 349, 427, etc.

A Balustrade is a similar construction, but lightened by being broken into balusters, as shown in Fig. 148, p. 55.

An Eaves Course is a projecting course formed under the lower edges of the slopes of a roof (the *eaves*), either merely for ornament, or to support a gutter. See Figs. 348, 524.

This, and any other course that projects over the wall, is called a *sailing course*, and should be throated to keep the wet off the wall below.

The Plinth [1] is a projecting base to a wall, which increases its stability; when not required for this purpose it is nevertheless sometimes added for the sake of appearance.

The kind of plinth varies greatly, according to the style of the building—from a plain offset in the thickness of the wall, to a most elaborate and highly ornamental base.

[1] Sc. *Intake.*

The upper surface of the projection of the plinth should be formed so as to throw off the rain.

In common buildings, with low walls, the plinth is generally omitted.

The plinth in Fig. 15 is marked P; see also Fig. 122.

The String Course is a horizontal course (see Fig. 15), often of stone, carried round a building, chiefly for ornament. If, however, the stones are well connected together, it forms a strong band round the walling, and is a source of strength.

The sills or lintels of windows are frequently continued throughout the length of the building, so as to form a "*Sill course* or *Lintel course*."

The string courses in Fig. 15 are marked S and S_1; the latter may, in some cases, form part of the cornice, and is then called a *Necking*.

Corbelling.—In many cases it is necessary to project certain courses of a wall beyond the face, in order to support wall plates, (Figs. 119, 416), for ornament in cornices (Fig. 118), to gain increased base for a chimney or wall above (as in Fig. 431), or in "gathering[1] over," or reducing an opening where an arch cannot easily be turned.

This is done by corbelling or projecting each course beyond the one last laid. If the weight to be carried is very great, the portion corbelled out will be proportionately deep, and the projection of each brick or stone should never be greater than $\frac{1}{3}$ of its bearing on the course below. The whole of the work corbelled out should not project more than the thickness of the wall from which it is corbelled out.

APERTURES IN WALLS.

The apertures required in walls are chiefly those for doors and windows.

Heads.—Each opening is generally closed at the top, either by an arch, as shown in Figs. 94, 98, etc., or by a "lintel" of stone, as in Fig. 143.

In many cases the head is of an ornamental character, weak in itself, and requires to be protected from undue pressure by a relieving arch, as described at page 52.

Jambs.—These are the sides of the openings, and may either

[1] Sc. for "gatherings"—*Incomes* or *Oncomes*.

be square, or formed with recesses to receive the frame for the door or window.

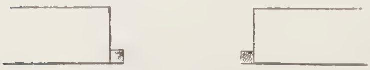


Fig. 16. *Square Jambs, no Reveal.*

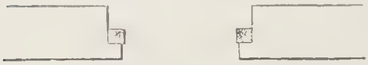


Fig. 17. *Reveal with Square Jambs.*

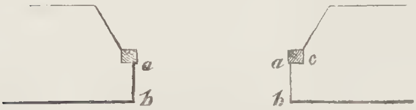


Fig. 18. *Reveal with Splayed Jambs.*

Reveals [1] are the portions of the sides of the openings left in front of the recesses for the frames (*a b* in Fig. 18). They are probably so called because they are revealed, or exposed to view, whereas the rest of the sides of the opening is generally hidden—the recesses by the frame which fits into them; and the remainder by linings.

The jambs behind the reveals may either be *square*, as in Fig. 17, or *splayed*, as in Fig. 18. Openings with splayed jambs weaken the wall more than when the jambs are square. They are, however, convenient in order to afford room for shutters, etc.

The thickness of the reveal is generally from $4\frac{1}{2}$ to 9 inches in brickwork, or from 6 to 12 inches in stone, but varies according to circumstances.

Sills.[2]—The lower side of the opening is generally finished, both in brick and stone walls, with a sill of stone in one piece, and about 5 or 6 inches longer than the opening. This forms the base of the window, and supports the oak sill of the sash frame.

Window Sills should be set so as to bear only on the ends, the intermediate portion being left quite clear, with a hollow space underneath, as the weight of the piers of the window will probably cause a greater settlement in the wall under the ends of the sill than under the centre, in which case the sill would be pressed upwards in the middle, and broken. The space is subsequently pointed up.

Sills should project at least 2 inches over the face of the work and be throated so that they may keep the wet off the wall below them.

Different ways of finishing the ends of sills are shown in the chapter on Joinery, Part II.

Door Sills are also of stone, in a single piece, except for internal doorways, where they may be of oak.

[1] The term reveal is somewhat loosely used, and is often applied to the width *a c* required for the frame.

[2] Sc. *Sole.*

Holes are sunk in these sills to receive the studs at the foot of the door frame.

The sill of an external doorway is generally formed by a stone step (see chapter on Joinery, Part II.)

WOOD BUILT INTO WALLS.

Timber should be kept out of walls as much as possible. The evils produced by building in large pieces of timber will be pointed out in Chapter IV. It is, however, frequently necessary to introduce pieces of wood in walling for different purposes, in which case they should be as small as practicable.

When the ends of timbers, such as girders, joints, tie-beams, etc., have necessarily to be built into walls, they should rest in chambers prepared for them, so that there may be a free circulation of air round the timber.

Wall Plates[1] are described at p. 127. They are sometimes built into the wall, but are there liable to the same objection, in a lesser degree, as bond timbers (see Chapter IV.)

TEMPLATES are short wall plates intended to support particular beams,—frequently they are of stone or iron.

Wood Lintels are beams over openings, such as those for doors or windows, shown in Fig. 99; but they should never be used without a relieving arch as shown in that figure (see p. 31), and they may be replaced by flat arches, or by cement concrete beams made with ashes or breeze from gasworks, so as to admit of the woodwork being nailed to them.

The arches and concrete have an advantage over wood lintels, inasmuch as they are not liable to destruction by fire or decay.

> *Rule.*—Thickness of lintel in inches should be equal to span in feet; that is, thickness of lintel $= \frac{1}{12}$ span, or some take it $= \frac{1}{8}$ span. The ends of the lintel should, as a rule, bear 9 inches on the walls, but $4\frac{1}{2}$ inches' bearing is often considered sufficient.

Bressummers are beams, either of wood or iron, spanning wide openings, and generally supporting a wall above.

Wood Bricks[2] are pieces of timber built into brick walls, in order that the necessary woodwork of the building may be secured to them.

They should be of the shape of the bricks in use, and equal in

[1] Ir. *Tassels.* [2] Sc. *Dooks.*

thickness to one of those bricks and *two* mortar joints, so that the rough surfaces of the adjacent bricks may have a firm grip on the wood. If wood bricks are imbedded in mortar they are nearly sure to become loose.

Several examples in which wood bricks are used are shown throughout these notes. Fig. 96 gives the arrangement of the wood bricks for securing a door or window frame.

Pallets or Wood Slips are flat pieces of wood, about 9 inches long, 3 inches wide, and $\frac{3}{8}$ inch thick. They are built into the joints of brickwork or masonry, to fulfil the same object as wood bricks, and have to a great extent superseded them, as they shrink less, and do not leave such a gap in the wall if they decay or are burnt out.

Wood Plugs are used in masonry, and sometimes in brickwork, for the same purpose as wood bricks. When anything is to be nailed to a wall, a plug should be driven in first, as the nail will not hold in the masonry.

Plugs should be about 4 to 6 inches long, $1\frac{1}{2}$ or 2 inches wide, and about $\frac{1}{2}$ inch thick, and in order to give them a better hold on the masonry they are cut with a twist, so that the grain of the wood runs obliquely across their thickness, and their sides are not parallel but splayed and in winding.

Great injury is often done to walls by driving wood plugs into the joints, as they are apt to shake the work, especially if it has been recently built. It is better to cut holes for the plugs in the solid stone or bricks.

Examples of plugging are given in Part II., chapter on Joinery.

Tubular Bricks with Wood Plugs.—To avoid driving plugs into masonry, tubular bricks are sometimes built in the required positions, with plugs driven into the hollow spaces in their interiors. *Pallete Bricks*, which have a rebate of dovetail-shape section formed along the upper outer edge to hold a fillet, are also used.

Substitutes for Wood Bricks.—If it is desired to dispense altogether with wood in the walling, small double strips of hoop iron may be placed in the joints at every point where a nail is to be driven. These firmly grip the nail, which is driven in between them. Strips of lead may be used for the same purpose.

Concrete Bricks, made of 6 parts breeze from gasworks and 1 part Portland cement, a material which will allow nails to be driven into it, are also used as a substitute for wood bricks.

CHAPTER II.

BRICKWORK.

GENERAL REMARKS ON BRICKWORK.

IN order to obtain good brickwork the following points should be attended to.

The bricks must be sound and well shaped. (See Part III.)

The mortar should be of good quality (see Part III.), carefully mixed, and used stiff.

A good bond should be preserved throughout the work, both laterally and transversely. All bed joints should be perpendicular to the pressure upon them; that is, horizontal in vertical walls, radial in arches, and at right angles to the slope of battering walls.[1]

In walling, the courses must be kept perfectly horizontal, and the arrises plumb. The vertical joints should be directly over one another,—this is technically called "keeping the perpends,"—if it is neglected the courses are overrun and "bats" become necessary.

Joints.—The joints should all be full of mortar, close, well flushed up, and neatly struck or pointed as required.

In good brickwork they should not exceed $\frac{3}{8}$ inch in thickness, but with badly-shaped rough bricks the beds of mortar are necessarily made thicker, in order to prevent the irregularities of the bricks from bearing upon one another, and causing fracture.

Both bricks and mortar-joints should be of uniform size and quality in all parts of the work.

Size of Bricks.—As stated in the chapter on materials (Part III.) bricks are made of different sizes; but by far the most common in England are those about $8\frac{3}{4}$ or 9 inches long, $4\frac{1}{4}$ to $4\frac{1}{2}$ inches wide, and $2\frac{1}{2}$ to $2\frac{3}{4}$ inches thick, which alone will here be treated upon.[2]

Bricks of all dimensions are laid on the same principles.

[1] A "*battering*" wall is one which is not vertical, but built with an inclination or "*batter*."

[2] For R.I.B.A. Standard Brick Dimensions, see R.I.B.A. Kalendar 1903-1904.

In nearly all cases bricks built in walling are laid upon their sides, occupying 9 inches × $4\frac{1}{2}$ inches on plan.

A course is a horizontal slice of the wall taken between two bed joints, and is of a depth equal to that of a brick and one mortar joint.

A "*bat*" is a broken brick, and is called a $\frac{3}{4}$ bat, $\frac{1}{2}$ bat, etc., according to the proportion it bears to a whole brick.

Headers are bricks whose lengths lie across the thickness of the wall. Those visible on the outside of the wall each show an end in the face, or back.

Stretchers are the bricks which lie parallel to the length of the wall. Those visible on the exterior each show one side in the face, or back of the wall.

Heading courses are those showing no bricks but headers in the face.

Stretching courses are those containing in the face stretchers only.

Thickness of Wall.—The thickness of a wall is the distance from the face to back, and is expressed in terms of a brick, thus:—a half-brick wall is $4\frac{1}{2}$ inches thick; a one-brick wall is 9 inches thick; a brick and a half wall is $13\frac{1}{2}$ inches (generally called 14 inches) thick, and so on.

Depth of Courses.—It is often specified that 4 courses should not exceed 12 inches in height. This assumes $2\frac{1}{2}''$ for the thickness of each brick and $\frac{1}{2}''$ for each joint. It is better however to specify that the depth of 4 courses should not exceed the thickness of 4 dry bricks, of the kind to be used, by more than $4 \times \frac{3}{8}''$ or 4 times whatever thickness of mortar joint is decided upon.

Bond.—The meaning of this term, and the general characteristics of a good bond, have been described at p. 2.

It was there shown that a wall may appear on the face to be well bonded, when in fact there is no bond at all between its front and back.

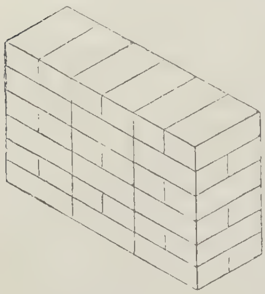


Fig. 19.

Fig. 19 shows a wall composed of courses of headers and stretchers alternately. By this arrangement thorough bond is obtained across the thickness of the wall, as each header overlaps two stretchers; but it will be seen that, as the length of each brick is exactly twice its width, every alternate vertical joint coincides throughout the whole depth of the wall, which is thus divided into several independent vertical strips or piers, having no bond or connection with one another.

This is manifestly a weak and defective arrangement. The remedy for the evil is the use of "closers."

CLOSERS are pieces of brick (*c c c*, Fig. 20) inserted in alternate courses, in order to prevent two headers from being exactly over each stretcher, and thus to obtain a *lap*.

Queen closers are bricks cut longitudinally in half, or specially made of the size and shape of half a brick. They are inserted next to the last bricks at the angles of the wall, in alternate courses, as at *c c c*, Fig. 20, and being each only half the width of a brick (*i.e.* $2\frac{1}{4}$ inches), have the effect of causing every brick in these courses to be placed $2\frac{1}{4}$ inches farther from the corner than it is in Fig. 19. The bricks of the intermediate courses remain in the position shown in that figure, and the consequence is that the vertical joints of the courses containing closers, instead of coinciding with those of the courses above and below, are $2\frac{1}{4}$ inches beyond them in every case, and thus *straight* vertical joints are avoided.

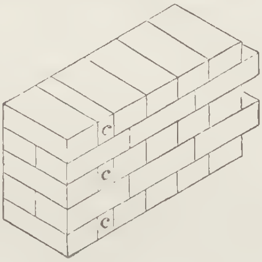


Fig. 20.
Wall with Queen Closers.

Closers should, if possible, be arranged so as to extend right through the thickness of the wall.

As it is not easy to cut a brick longitudinally in half without breaking it, it is frequently cut into quarters, each of which is a half closer, and two placed end to end form a queen closer.

King closers are bricks cut to this shape, so that, in the face of the wall, they present the same appearance as an ordinary $\frac{1}{4}$ brick closer; but the tail of the brick, being left on, strengthens the work considerably, and is a great advantage in some situations, such, for example, as that shown in Fig. 105 (see p. 33).

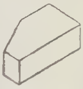


Fig. 21.

Three-quarter bats are sometimes used instead of closers.

If so, they should be placed at the extreme end of the wall, so as to form the quoin bricks of the stretching courses, as at *b b b* in Fig. 22.

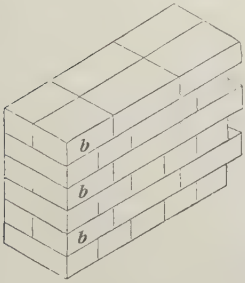


Fig. 22.
Wall with $\frac{3}{4}$ Bats.

They may, however, be used in the same position in the heading courses, and for all thicknesses of walls either in English or Flemish bond. The use of $\frac{3}{4}$ headers is expensive and wasteful, for each of them spoils a whole brick, the piece cut off being useless; whereas, with ordinary closers, every bit of brick may be used up.

DIFFERENT BONDS.

Heading Bond consists entirely of headers. As bricks vary in length more than in any other dimension, their ends project unequally on the face, and it is difficult, therefore, to make neat work with this bond, especially in walls one brick in thickness.

There is very little longitudinal strength in the wall, and the pressure on each brick is distributed over a comparatively small area (see Fig. 23 compared with Fig. 1).

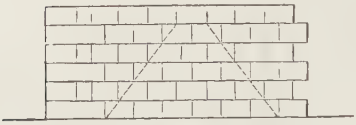


Fig. 23. *Heading Bond.*

Heading bond is chiefly useful in working round sharp curves, where the angles of stretchers would, unless cut off, project too much, and spoil the curve. When used in this position, the sides of the bricks must be roughly cut, so as to radiate from the centre of the curve, or a curve may be gained, when it is not too sharp, by making the joints of wedge shape wider on the outer face of the curve.

In walls of heading bond more than one brick thick, a line of bats or half-bricks must be introduced, in alternate courses, to form the transverse bond.

Stretching Bond consists entirely of stretchers, and is adapted only for walls $\frac{1}{2}$ brick thick.

In walls beyond that thickness (see Fig. 1) it is practically no bond at all. There is no transverse tie. The block is divided into a number of independent $4\frac{1}{2}$-inch walls.

Stretching bond is, however, commonly used in chimneys when their external walls are only $4\frac{1}{2}$ inches thick, and has, in consequence, received the name of "*chimney bond.*"

English Bond shows both on face and back, stretching and heading courses alternately, closers being inserted as shown, and as before described, to give the lap (see Fig. 24).

Fig. 24. *English Bond.*

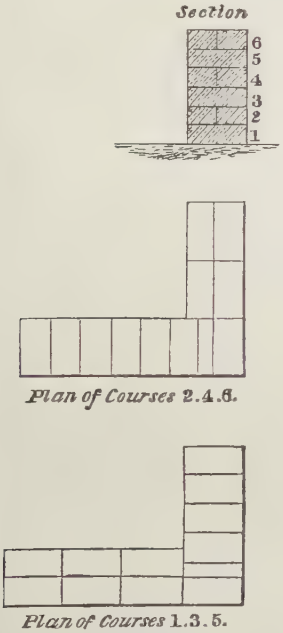
This is the best bond for work generally. It gives the most simple combination for longitudinal and transverse strength.

Figs. 25, 26, 27, give plans of the courses, and a section of a wall in English bond one brick thick; and Figs. 28, 29, 30 afford the same information for a wall $1\frac{1}{2}$ brick thick.

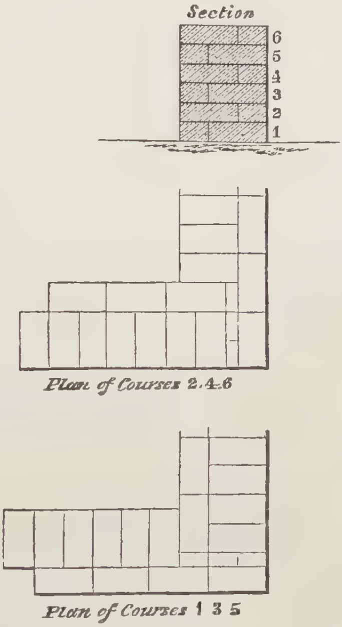
In the last-mentioned wall each course contains a row of headers and one of stretchers, the headers and stretchers appearing alternately on opposite sides of the wall.

This latter will be found to be the case in every wall whose thickness is an *uneven* number of *half bricks.* In such, every course showing stretchers on the face will show headers at the back, and *vice versa.* See Figs. 35, 36, and others.

In a wall whose thickness is a multiple of a *whole* brick, that is, of 9 inches, every course will show the same both on the front and back of the wall—that is, either stretchers on both sides, or headers on both sides, in the same course.



Figs. 25, 26, 27.
English Bond, 9-*inch wall.*



Figs. 28, 29, 30.
English Bond, 14-*inch wall.*

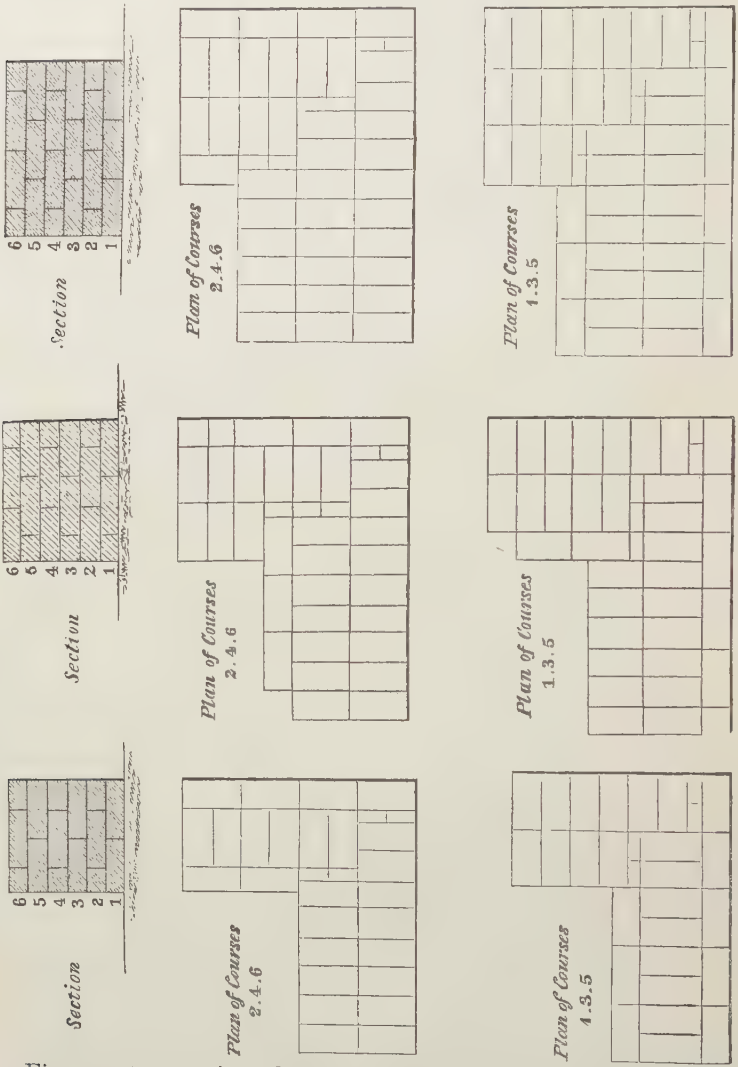
In walls more than 14 inches thick, though the external rows of bricks are headers or stretchers in the alternate courses; yet those within the wall are all laid as headers. Stretchers within the wall would cause straight joints.

The bricks should not break joint with each other in the same course. The transverse joints should be straight, as shown.[1] Any attempt to break these joints, though it may look better in

[1] See p. 20.

the plan of each course, leads to a large number of vertical joints being brought together in the body of the work (see pp. 20 and 26).

ENGLISH BOND.



Figs. 31, 32, 33. *English Bond, 18-inch wall.*

Figs. 34, 35, 36. *English Bond, 1' $10\frac{1}{2}''$-wall.*

Figs. 37, 38, 39. *English Bond, 2' 3''-wall.*

Figs. 31 to 39 give plans of the courses, showing the junction at angles, and sections of walls from 2 to 3 bricks thick.

It will be seen that in walls more than 14 inches thick there is a deficiency of stretchers in the centre of the wall. This can best be remedied by introducing courses of bricks placed diagonally, the bond for which will be explained in Chapter IV.

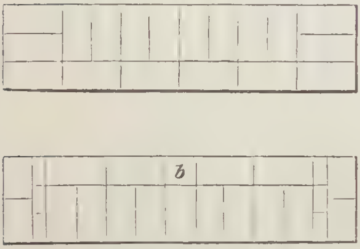
The number of stretchers is less in proportion as the wall grows thicker, being as follows:—

In a	$1\frac{1}{2}$-brick	wall the	number of	stretchers is	$\frac{1}{2}$	that of the	headers.
"	2	"	"	"	$\frac{1}{3}$	"	"
"	$2\frac{1}{2}$	"	"	"	$\frac{1}{4}$	"	"
"	3	"	"	"	$\frac{1}{5}$	"	"

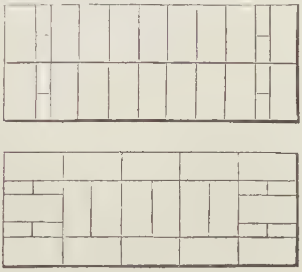
In English bond there are twice as many vertical joints in a heading course as there are in a stretching course; therefore the vertical joints between the headers must be made thinner than those between the stretchers; for if two headers were laid so as to occupy a greater length than one stretcher, the $\frac{1}{4}$-brick lap obtained by the aid of the closer would be encroached upon, and would soon disappear.

The figures given above show the bond used for walls meeting at the ends to form a right angle, which is the most common case in practice.

If, however, a wall is detached and terminated only by its



Figs. 40, 41.
English Bond, detached 14-*inch wall.*



Figs. 42, 43.
English Bond, detached 18″-*wall.*

ends being cut off square, as shown in Figs. 40 to 43, the bond has to be slightly modified, so as to give the ends a neat finish.

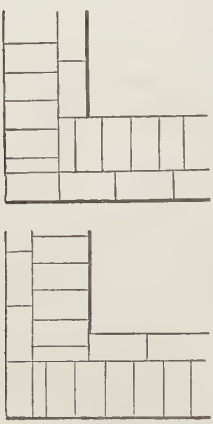
In such walls, when they are of an uneven number of half bricks in thickness, a peculiarity must be noticed—both sides do not present the same appearance. The closers show both in the stretching and heading courses alternately; but in walls whose length is equal to that of an even number of half bricks, a bat must be introduced among the stretchers on the face in which the closers occur in the stretching courses, whilst in walls whose length is equal to that of an uneven number of half bricks, the bats will show in the stretching courses which do not contain the closers; the face with the bats should form the back of the wall.

Fig. 41 shows an example of this; the bat referred to being at *b*.

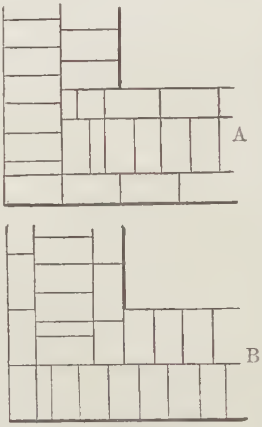
Figs. 42, 43 give plans of two courses of an 18-inch wall, with

returned ends. Want of space forbids any further illustration of such walls; but the student should draw them for himself, bearing in mind what is stated above, and remembering also that the returned ends of thick walls should be treated so as to show a bond similar to that on the faces of the walls.

English Bond with Broken Transverse Joints.—It has been said above (see p. 17) that the joints across the thickness of walls should be unbroken. This has, however, been objected to on the ground that in bad work—the vertical joints of which are not flushed up, and the face not properly pointed—the rain may be blown through these half-empty straight transverse joints, so as to make the wall damp on the inside. A bond with broken transverse joints is therefore often advocated and adopted, but it has serious defects, which will now be pointed out:—



Figs. 44, 45.
Faulty English Bond, 14-*inch wall.*



Figs. 46, 47.
Faulty English Bond, 18-*inch wall.*

Figs. 44, 45 show two courses of a 14-inch wall, and Figs. 46, 47, the same of an 18-inch wall with broken transverse joints. Fig. 48 is a plan of the two courses (A and B) of the 18-inch wall, one laid upon the other, A being shown in dotted lines, and B in thin lines. The thick lines, marked *y*, show portions of the joints which coincide and fall into the same vertical plane.

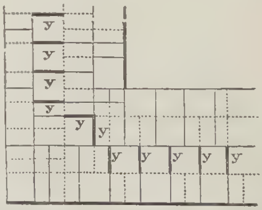


Fig. 48. *Faulty English Bond,* 18-*inch wall. Two Courses superposed showing Straight Joints.*

It will be seen, therefore, that the wall contains splits (marked *y*) $4\frac{1}{2}$ inches wide, extending from top to bottom of its height, and occurring at intervals of $4\frac{1}{2}$ inches throughout its length.

These are a source of weakness, and may be avoided by adopting the simple plan recommended at p. 17, and shown in Figs. 32, 33—that is, by making the transverse joints run straight from face to back of the wall.

When two courses of a wall so bonded are drawn in position, one over the other, as in Fig. 49, it will be seen that the vertical joints coincide only in one place for a length of 9 inches, as shown by the thick line.

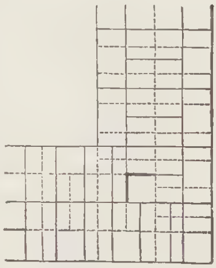


Fig. 49. *Proper English Bond*, 18-*inch wall. Two Courses superposed.*

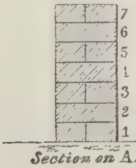
The bond of Figs. 44, 45 tested in the same way, will show similar defects to those described, and the same will be found in walls of all thicknesses where it is attempted to break the transverse joints. The student will be able to test any such examples for himself by drawing two courses, one above the other, as above described.

Thus, however good the workmanship may be, the use of broken transverse joints can result only in walls containing defects which must injure their strength, whereas with straight transverse joints the wall is properly bonded in almost every part (see Fig. 49); and if the work is properly flushed up and pointed, as it should be, there is no danger of rain finding its way through the wall.

Flemish Bond shows in elevation (either on one or both faces of the wall, according to the variety of the bond adopted), in every course, headers and stretchers alternately; every header is immediately over the centre of a stretcher in the course below it; closers are inserted in alternate courses next to the corner headers to give the lap.

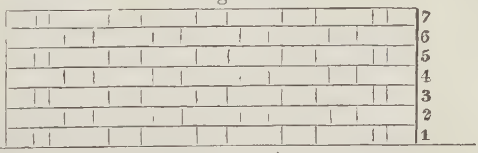
The appearance of the face which distinguishes Flemish bond is shown in Fig. 50.

Fig. 53.

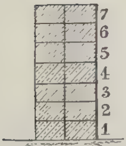


Section on A.B

Fig. 50.



Elevation of Flemish Bond



Section on C D

Fig. 54.

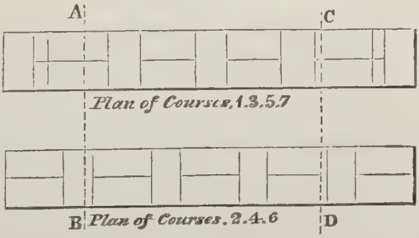


Fig. 51.

Fig. 52. *Flemish Bond, 9-inch wall.*

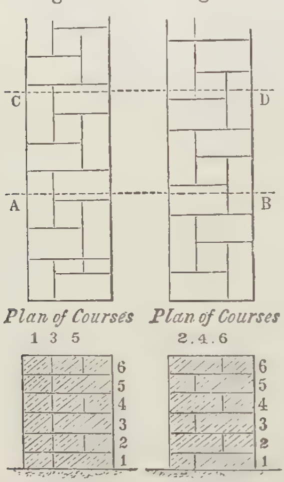
Figs. 51 to 54 give plans of two courses and sections taken at two points of a 9-inch wall in Flemish bond.

For thicker walls the back may either be in Flemish bond, like the front, or in English bond: this leads to two or three varieties of Flemish bond, which will now be described.

Double Flemish Bond implies that both the front and back of the wall are built in Flemish bond, presenting an elevation like Fig. 50 on both faces of the wall.

Figs. 55 to 62 give plans of two courses and sections taken at two points of a 14-inch and an 18-inch wall respectively in double Flemish bond. In each case two sections are given—one on A B, through the strongest, and the other on C D, through the weakest part of the wall.

Fig. 56. Fig. 55.

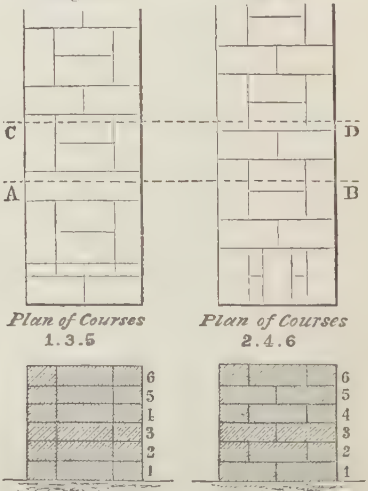


Section on C.D Section on A.B

Fig. 58. Fig. 57.

Double Flemish Bond, 14-inch wall.

Fig. 60. Fig. 59.



Section on C.D Section on A.B

Fig. 62. Fig. 61.

Double Flemish Bond, 18-inch wall.

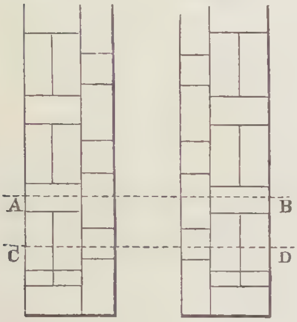
In these it will be seen that, at certain parts of the wall, straight joints occur throughout its whole depth, as shown by the section on C D in each case. Moreover, in all walls of an odd number of bricks in thickness, a large number of half bricks have to be used in the centre.

The above are objections to this form of bond; and they are greatly aggravated by the usual method of doing the work, shown in Figs. 63 to 70.

Double Flemish Bond with False Headers.—Figs. 63 to 66

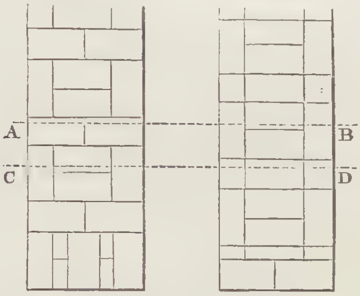
show plans of two courses, and sections taken at two points of a 14-inch wall; and Figs. 67 to 70 give the same information for an 18-inch wall built in double Flemish bond with false headers. In the 14-inch wall it will be noticed that the headers consist only of half bricks, having no bond with the interior of the wall.

Fig. 64. Fig. 63.

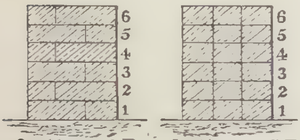


Plan of Courses 1.3.5 *Plan of Courses* 2.4.6

Fig. 68. Fig. 67.



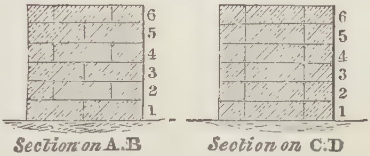
Plan of Courses 1.3.5 *Plan of Courses* 2.4.6



Section on A B *Section on* C D

Fig. 65. Fig. 66.

Double Flemish Bond with False Headers, 14-*inch wall.*



Section on A B *Section on* C D

Fig. 69. Fig. 70.

Double Flemish Bond with False Headers, 18-*inch wall.*

In the 18-inch wall only the headers in every alternate course are half bricks. Thus, in the 14-inch wall all the headers, and in the 18-inch wall half the entire number of headers, are false.

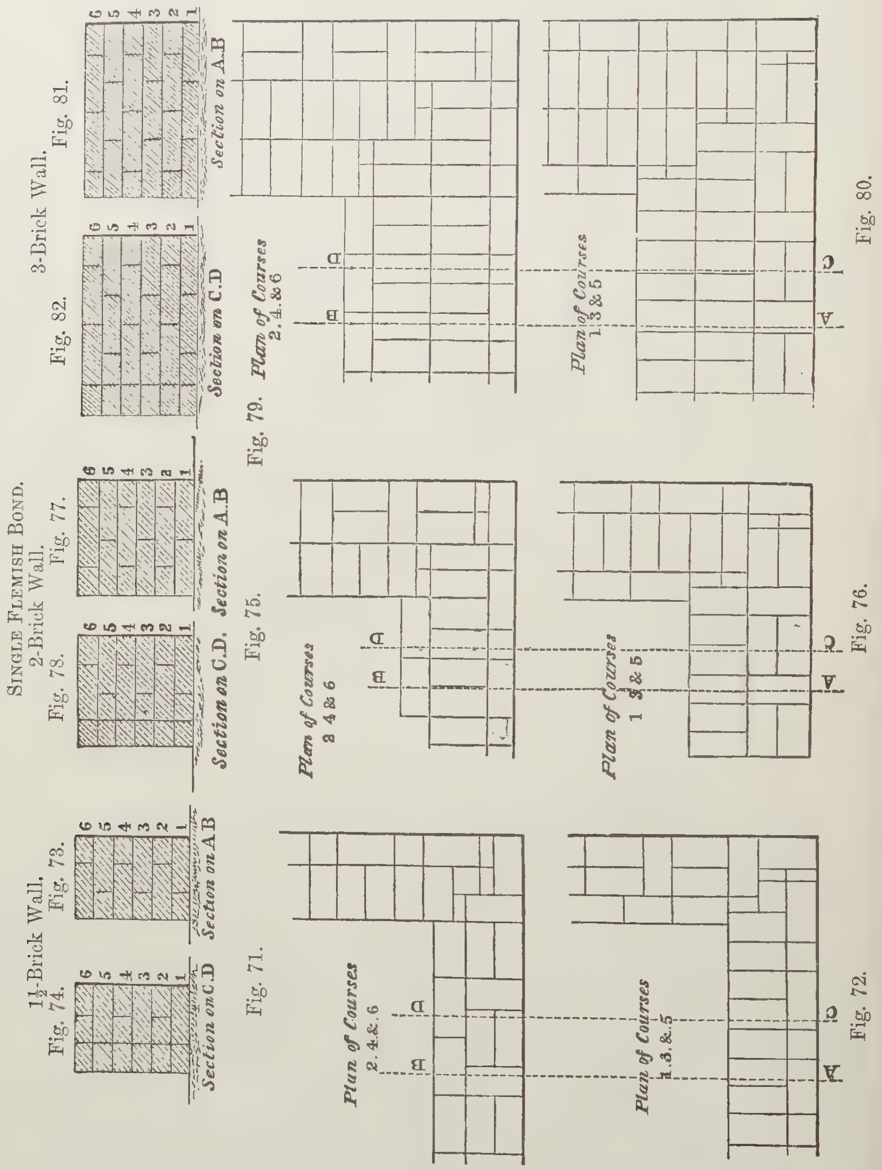
The effect of this is to cause a straight joint through the whole depth of the wall on both sides, as shown in the section on C D in each case.

This arrangement is often adopted when the facing is of superior bricks, in order to economise them. The half bricks look like headers, though they are useless for the bond.

Single Flemish Bond consists of Flemish bond on one face of the wall, with English bond on the other.

This combination is made in order that the work may on the face look like Flemish bond, the appearance of which is, or was, supposed to be superior to that of English bond, and, at the same time, to get rid of the defects of Flemish bond in the interior of the wall.

Figs. 71 to 82 give plans of two courses and sections taken at two points of walls of different thicknesses in single Flemish bond.



The sections on C D show that the straight vertical joint

which occurs on both sides in most cases of double Flemish bond, is now confined to the Flemish facing.

It will be noticed that false headers are used in alternate stretching courses throughout the Flemish facing. These can be avoided, as before explained; but they are more economical, and are therefore generally preferred, though their use leads to bad work in more ways than one (see Chapter IV.)

In some cases a combination of the two methods is adopted. Some of the headers in every course are left entire—the intermediate ones being broken in two.

The consideration of the evils connected with the practice of facing walls with work superior to that in the backing is entered upon in Chapter IV.

Comparison of English and Flemish Bond.—English bond is, upon the whole, to be preferred to Flemish bond for strength, as it contains a larger proportion of headers. The only advantage claimed for Flemish bond is its appearance, which is preferred by many, and has led to its use in brick buildings of a superior class.

In 9-inch walls a better face can be shown on both sides by Flemish than by English bond, as the unequal length of headers causes a rough face when there are many of them.

In walls of 1½ brick in thickness the strength is not so much impaired by using Flemish bond, as it is in thicker walls.

For thick walls English bond should be used, if possible: but, if Flemish bond is required, it should have a backing of English bond, as described at p. 23, unless it is to show a fair face on both sides.

Some bonds not in very common use, such as Raking Bonds, diagonal and herring-bone, and garden bond, English and Flemish, are described in Chapter IV.

Inferior forms of English Bond.—Figs. 83, 84 are plans of two courses of an 18-inch wall, showing the bond frequently recommended in books. It will be noticed that course A has broken transverse joints, but the advantages claimed for these (see p. 20) are neutralised by the straight transverse joints in course B; and upon further investigation it will be seen that the defects caused when all the transverse joints are broken are aggravated by this mixture of the two systems.

Fig. 85 is the plan of two courses (one laid upon the other

of the 18-inch wall bonded as shown in Figs. 83, 84. The course A is uppermost, and shown in thin lines; course B below being drawn in dotted lines. Those portions of the joints which coincide in both courses are shown in thick lines.

It will be seen, therefore, that the centre of the wall for more than half its thickness is split up by these coincident or "straight" joints, into vertical slabs having no connections with one another except on the faces of the wall.

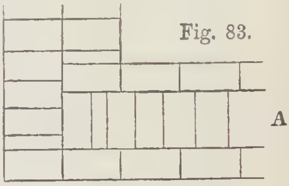


Fig. 83.

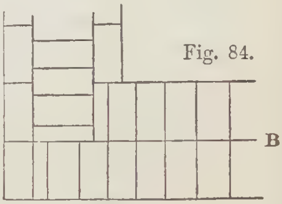


Fig. 84.

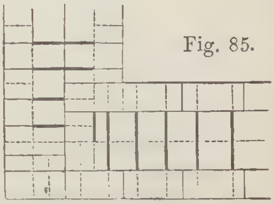
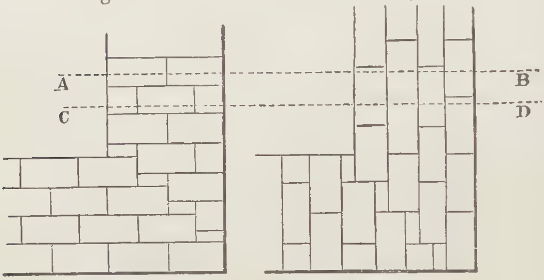
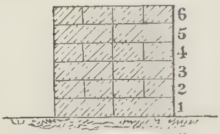


Fig. 85.

Fig. 86. Fig. 87.

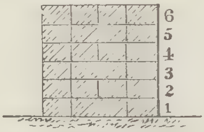


Plan of Courses 1.3.5 *Plan of Courses* 2.4.6



Section on A.B

Fig. 88.



Section on C.D

Fig. 89.

Inferior forms of English Bond, showing Defects.

The bond shown in Figs 86, 87 is frequently recommended for angles formed by walls of considerable thickness, but is also open to objection, although on paper each course presents a symmetrical appearance.

It will be seen by the sections that although each course is well bonded in itself, and appears to be of a strong construction, false headers are used, and there is no part of the wall which is not split up by one or more vertical joints extending throughout its whole height.

The merits of respective bonds and the defects of some forms frequently recommended, are fully discussed in Sir Charles Pasley's treatise on brickwork, from which much of the information given above is taken.

Sir Charles Pasley recommends that a student desirous of thoroughly understanding the various bonds, and of testing their respective merits, should build them for himself with model bricks; or if this cannot conveniently be done, he should at least draw the courses, one above another, as in Fig. 49, in order to ascertain whether any of the joints coincide so as to form splits in the wall.

JUNCTION OF WALLS AT RIGHT ANGLES.

Salient Angles.—Several examples of these are shown in Figs. 25 to 39, 71 to 80, and others.

Re-entering Angles.—*Junction of two Brick Walls.*—Figs. 90, 91 are the plans of two courses of the junction between a main wall $2\frac{1}{2}$ bricks thick, and a wall at right angles to it 2 bricks thick, both in English bond.

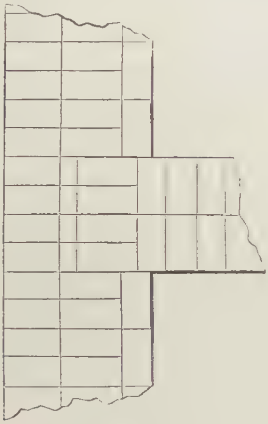


Fig. 90.
Junction of Brick Walls.

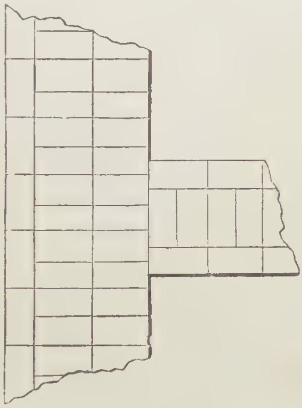


Fig. 91.
Two alternate Courses.

In every alternate course of the principal wall, exactly opposite the junction, is inserted a row of closers, in length equal to the thickness of the other wall (see Fig. 90).

The intermediate courses are built as usual in both walls, and merely butt against one another, without bond, as in Fig. 91.

A course of stretchers may, however, be inserted occasionally to improve the bond between the walls, although it leads to straight joints in the walls themselves.

Hoop-iron bond (see Chap. IV.) may be used with advantage in such positions.

The bond for external or internal re-entering angles is shown in Figs. 25 to 39, and in Figs. 71 to 80.

Junction of a Brick and Stone Wall at right angles.—This may be effected in either of two ways:—

1. Stones at short vertical intervals, each equal in height to an exact number of courses of the brickwork, may be allowed to protrude from the stone wall into the brickwork.

2. The brickwork may penetrate the stonework in blocks, each of which consists of about 4 courses in depth, and is separated by about the same depth from the blocks above and below it.

The former plan is the stronger, and has the advantage of clearly showing the bond at any time; but with the former plan the brickwork must be plastered, if the appearance of the stone bonds is objected to.

GAUGED WORK.

Bricks cut and rubbed to the exact shapes required, in order to get very fine joints, are frequently used in the "dressings" of brickwork, such as arches, quoins, etc.; this is termed "*gauged work.*"

Peculiar bricks, such as "red rubbers," "malm-cutters," etc., are made for the purpose, being softer, and easier to rub, but they are consequently more perishable than ordinary good bricks.

Gauged work is generally set in "putty,"[1] and the joints do not exceed $\frac{1}{10}$ to $\frac{1}{8}$ inch in thickness.

BRICK ARCHES.

Plain, Common, or Rough Brick Arches are those in which the bricks are not cut, or rubbed, so as to form voussoirs accurately radiating to a centre. The joints are therefore wider at the "extrados" than they are at the "intrados." Such arches are used for ordinary brickwork in tunnels, and concealed work generally.

Rough arches of small span are generally turned in half-brick rings, $4\frac{1}{2}$ inches thick, as shown at *h h* in Fig. 92. In arches of quick curve, with not more than 3 or 4 feet radius, this is absolutely necessary to prevent very large joints at the extrados.

Fig. 92 is the section of portions of small arches, of which one, *w w*, is turned in 9 inch rings consisting of headers. It will be seen

[1] Not the putty used by glaziers. For a description of this material see Part III.

that the mortar joints in this are much wider at the extrados than those of the portion *h h*, built in rings half a brick in thickness.

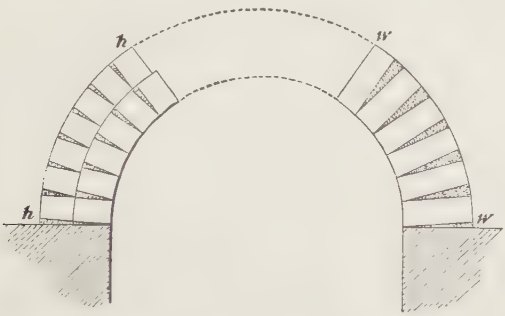


Fig. 92. *Brick Arch, showing Opening of Joints at Extrados.*

When wide joints necessarily occur on the extrados of an arch, they are often filled in with pieces of slate, and made as tight as practicable.

The plain or rough arches most usually required in buildings are those for relieving lintels over window and door openings (see Fig. 99), trimmer arches to support hearthstones (Fig. 299), the arches in chimney breasts (Chap. IV.), etc.

Rough-cut or Axed Arches have the bricks roughly cut with a bricklayer's axe to a wedge form, and are used over openings when the work is to be plastered, as relieving arches at the back of window and door heads (see Fig. 99), or in some cases as face arches.

Gauged Arches are built with bricks accurately cut, and rubbed down so as to radiate from the centre. They are used chiefly for external face arches over openings and recesses in superior work (see Figs. 93, 98).

Bricklayers frequently carefully rub only the portion of the joint near the face, cutting the back part right away, so that the arch does not bear equally, except just on the front edges of the bricks. This leads to the arch bulging forward, or to bricks dropping out of it altogether, and the pressure being all on the edges they readily splinter off.

These arches are generally built with special bricks, easier to rub, and of a larger size than common bricks.

When bricks of the ordinary size are used for straight arches, they are not long enough to be splayed at the ends to form the horizontal joints parallel to the soffit, as shown in Fig. 98. In

such a case, the ends of the bricks are left square, the real joints daubed over to conceal them, and false joints made for appearance to look like those in Fig. 98. This, however, is bad work, and should be avoided.

ARCHES OVER OPENINGS IN EXTERNAL WALLS.

In brickwork such openings are generally covered by a gauged (or sometimes axed) arch, which shows on the face of the wall for ornament, having a relieving arch on the inside to support the weight of the wall above (see Part II.)

The external arch may be "flat," "camber," "segmental," "semicircular," or struck to any curve, such as the semi-ellipse or parabola.

If the external arch is semicircular, segmental, elliptical, or parabolic, the relieving arch is of the same curve, and so generally are the door and window frames.

Segmental Face Arch.—Figs. 93 to 97 give the plan, exterior

Fig. 94. Fig. 95. Fig. 96.

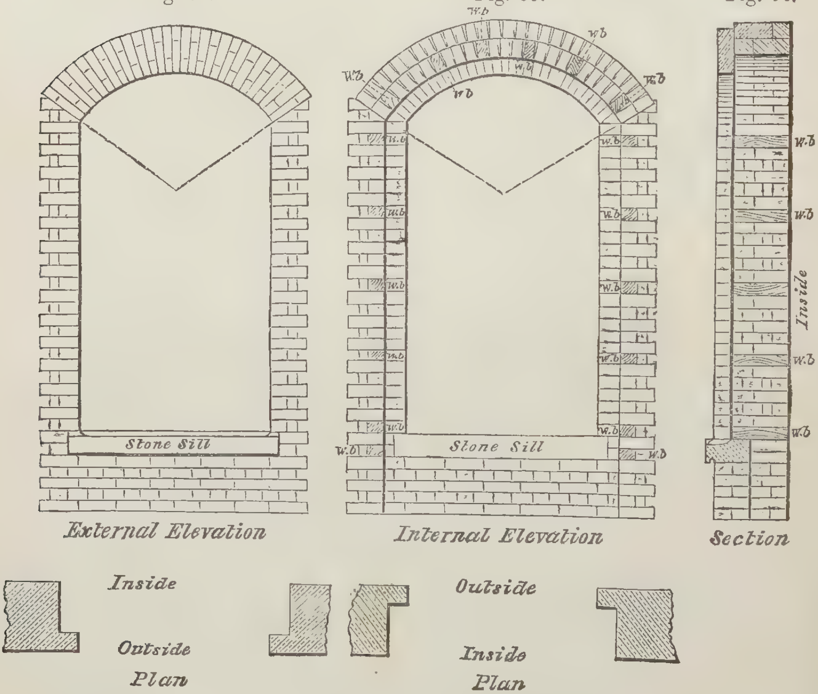


Fig. 93. Fig. 97.

Window Opening with Segmental Arched Head.

and interior elevations, and section, of a window opening with a segmental arched head.

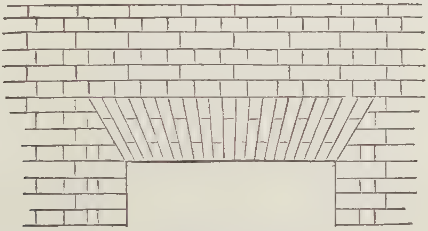
It will be seen that the gauged arch extends into the wall only the depth of the reveal (in this case $4\frac{1}{2}$ inches). As this arch has no connection whatever with the rest of the wall, it should be built with the greatest care.

A rough brick arch in two half-brick rings is turned over the opening in the remainder of the thickness of the wall, and contains wooden bricks, *w b*, or, in good work, plugs, to which the sash frame may be secured.

Wooden bricks, *w b*, are also built into the sides of the jambs, as shown, for the same purpose; but wood plugs or pallets (see p. 12) are frequently used instead.

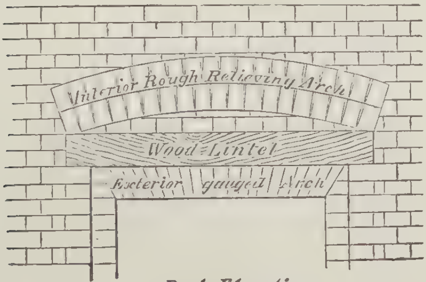
Semicircular Arches are arranged in exactly the same way as those just described, the only difference being in the curve of the soffit.

Straight Arch.—If the head of the opening is to be flat on the



Front Elevation.

Fig. 98. *Straight Arch Window Head.*



Back Elevation

Fig. 99. *Showing Relieving Arch.*

soffit, or nearly so, a straight gauged arch may be adopted, as shown in Fig. 98.

This gauged arch extends into the wall for a thickness of only half a brick. Behind it, the opening is spanned by a wood lintel, to which the frame of the door or window is fixed.

In order to protect the lintel from the weight of the wall above, a rough relieving arch is turned over it, as shown in the back elevation, Fig. 99. The portion between the top of the lintel and the soffit of the relieving arch is called the *core.*

Care must be taken that this relieving arch abuts on the wall clear of the ends of the lintel, otherwise, when the timber shrinks, rots, or is destroyed by fire, the arch would lose its supports and fall in.

Examples of wood lintels with relieving arches are given in the chapter on Joinery, Part II.

Another plan is to do away with the lintel altogether, and to substitute for it a flat or slightly cambered rough-axed arch like that in Fig. 101. In this wood plugs are inserted, to which the frame may be attached. An example of this form of construction is given in Part II.

Arches of this kind for wide spans may be supported by flat wrought-iron tension bars, extending along the soffit, and held up at short intervals by iron bolts passing through the depth of the arch, each secured by a plate and nut on the extrados.

A concrete beam (see p. 11) may be used instead of the flat relieving arch described above (see Part II.)

French or Dutch Arches (see Fig. 100) are sometimes adopted

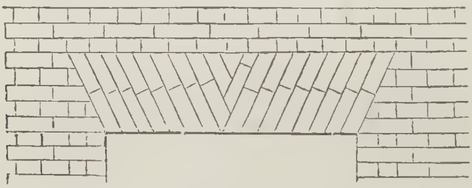


Fig. 100. *French or Dutch Arch.*

in walls that are to be stuccoed or plastered. They may also be used as flat relieving arches, but the construction is not theoretically a good one, and should never be adopted.

ARCHES OVER OPENINGS IN INTERNAL WALLS.

Arches over doors and other internal openings may be flat rough cut, or axed arches, containing wooden plugs, *ppp*, as

in Fig. 101; or a wood lintel may be placed over the opening, with a rough segmental relieving arch, similar to that in Fig. 99, the gauged arch shown in that figure being, of course, omitted. Of these constructions the last mentioned is commonly adopted. The use of rough-axed arches is not common, but it is advocated on the ground that they do away with the wood lintel, which is liable to destruction by fire or decay, and to become loose by shrinking. Lintels of concrete, as described at page 11, may be used, and have the same advantages as flat arches.

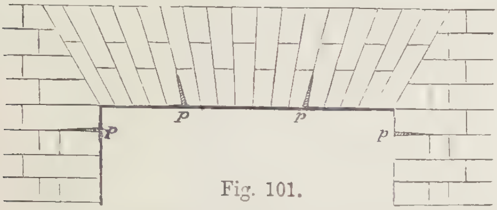


Fig. 101.
Rough axed Arch with Plugs.

JAMBS OF WINDOW AND DOOR OPENINGS.

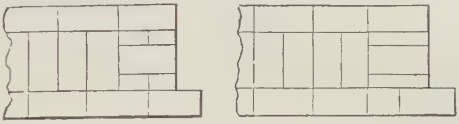
The method of forming these openings, with or without reveals of different kinds, has been referred to at page 10.

The depth of the reveal varies from $\frac{1}{2}$ a brick or $4\frac{1}{2}$ inches, to 9 inches or the length of a whole brick.

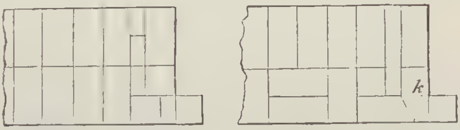
This depth depends upon circumstances, and a good deal upon fashion, which varies considerably from time to time.[1]

Reveal with Square Jambs.—Such a reveal for a 2-brick wall in English bond is shown in Figs. 102, 103, which give plans of two courses, the thickness of the reveal being half a brick in each case.

Figs. 104, 105 illustrate the arrangement for a similar reveal in Flemish bond. A king closer is inserted at *k*, to avoid using the small pieces shown in dotted lines.



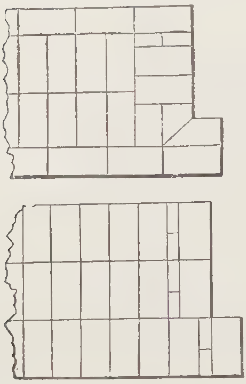
Figs. 102, 103.
½-brick square Reveal, 18″-wall, English Bond.



Figs. 104, 105.
½-brick square Reveal, 18″-wall, Flemish Bond.

[1] Section lv. of the Building Act says:—"All woodwork fixed in any external wall except bressummers and story posts under the same, and frames of doors and windows of shops on the ground story of any building, shall be set back 4 inches at least from the external face of such wall. But loophole frames and frames of doors and windows may be fixed flush with the face of any external wall.

Figs. 106, 107 show two courses of a 9-inch reveal with square jambs for a 3-brick wall in English bond.


Figs. 106, 107.
Whole-brick square Reveal, 2 feet 3-inch wall, English Bond.

Reveals are distinguished by the thickness of brickwork in front of the check left for the frame. Thus a half-brick reveal means a reveal such as those in Figs. 102 to 105, having a thickness of half a brick in front of the angle into which the frame will fit; while Figs. 106, 107, in which this portion is 9 inches thick, represent a "whole-brick reveal."

Of course, in walls more than one brick in thickness, the reveal may be either $4\frac{1}{2}$ inches or 9 inches in depth.

The reveals shown in Figs 102 to 107 are adapted for cased frames or heavy solid frames requiring a width of $4\frac{1}{2}$ or 5 inches. When lighter solid frames are used the width of the recess behind the reveal (*a c* Fig. 18) is often made only $\frac{1}{4}$ brick instead of $\frac{1}{2}$ brick, as shown in the figures.

It would be impossible, for want of space, to illustrate reveals of all the different dimensions, in walls of various thicknesses, but the examples given will assist the student in drawing any reveal required.

Reveals with Splayed Jambs in English Bond and Flemish Bond will be described in Chapter IV.

PARTS OF BRICK WALLS.

Footings.[1]—The general question of footings for walls will be considered in the chapter on Foundations, Part II. It will be

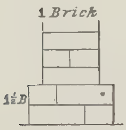


Fig. 108.
Footings, 9-inch wall.

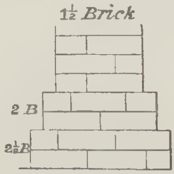


Fig. 109.
Footings, 14-inch wall.

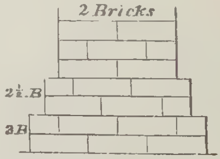


Fig. 110.
Footings, 18-inch wall.

sufficient now to place before the student the figures 108 to 112

[1] Sc. *Scarcements.*

giving sections of footings for brick walls from 1 to 3 bricks in thickness.

The plan of any particular course, whether "heading" or

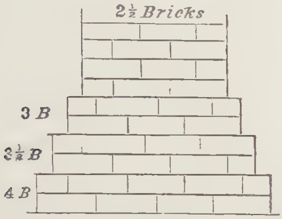


Fig. 111. *Footings, 1′ 10½″-wall.*

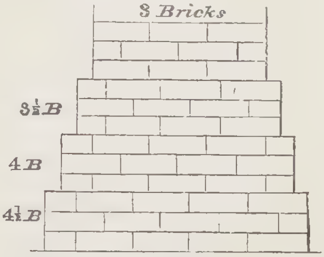


Fig. 112. *Footings, 2′ 3″-wall.*

"stretching," is the same as that of a similar course in a wall of the same thickness.

For example, the plan of the lowest course in the footings of Fig. 110 is the same as that of the lowest course in the wall three bricks thick, shown in Fig. 112.

The footings of buildings generally rest upon concrete, which is not shown in the figures (see Part IV.)

A good bed of concrete will effectually distribute the weight of a wall over the ground upon which it is built, and the gradually projecting courses of footings may, when bye-laws do not prevent it, often to a great extent, or in some cases entirely, be omitted.[1]

Quoins in brickwork can hardly be made stronger than the rest of the walling: they should, however, be built with great care, and are often constructed in gauged work, divided for appearance into blocks, which may be made to project slightly from the face of the wall. Stone quoins are often used with brick walls, or brick quoins with soft stone walls.

Copings.—The nature and object of copings for walls have been referred to at p. 7.

Stone copings are often used for brick walls, and are better than those formed with bricks, as they contain fewer joints, and may be of a less porous material.

Glazed pottery, vitrified brick, fire-clay, concrete blocks, and

[1] *The rule for footings in the Building Act* is as follows :—"The projection of the bottom of the footing of every wall on each side of the wall, shall be at least equal to one-half of the thickness of the wall at its base (unless an adjoining wall interferes, in which case the projection may be omitted where that wall adjoins), and the diminution of the footing of every wall shall be formed in regular offsetts, and the height from the bottom of such footing to the base of the wall, shall be at the least equal to two-thirds of the thickness of the wall at its base."

terra-cotta copings may also be used with advantage, for the same reasons.

The hardest and least porous bricks should be selected for copings, and should be set or pointed in cement.

Fig. 113 is a section of the common "brick-on-edge" coping. A double course of tiles or slates, in either case called "*creasing*," is sometimes substituted for the projecting course of bricks, marked A.

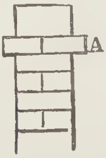


Fig. 113. *Brick-on-edge Coping.*

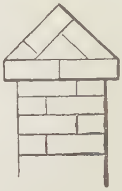


Fig. 114. *Brick Coping.*

Fig. 114 shows a brick coping of a more ornamental character.

Brick or clay-ware copings made in complete sections, such as those in Figs. 115 and 116, are far preferable to those built up of ordinary bricks, as they are generally of more impervious material, have fewer joints, and can be throated like the stone coping in Figs. 129, 131.

Fig. 115.

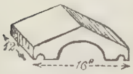


Fig. 116.

Cornices (see p. 8) may be introduced in brickwork with great effect by "corbelling" out the bricks without cutting them, and also by placing projecting bricks with their angles to the front of the wall, technically known as "*dogs'-teeth.*"

A simple brick cornice is produced by allowing every alternate header to project from the face $\frac{1}{4}$ or $\frac{1}{2}$ a brick.[1] Above and below these headers are courses of stretchers, projecting and receding $\frac{1}{4}$ brick respectively. Such a cornice is shown in Fig. 117, the moulded member on the top being a cast-iron eaves gutter.

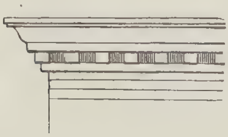


Fig. 117. *Brick Cornice with Gutter.*

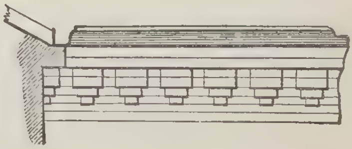


Fig. 118. *Brick Cornice with Gutter.*

Fig. 118 gives an elevation and section of a more elaborate brick cornice.

[1] Quarter-brick projections are generally bald and unsatisfactory in appearance.

Eaves Courses are formed by projecting bricks in a similar manner.

Corbelling (see p. 9).—Fig. 119 is the section of a wall corbelled out to carry a wall plate. In brickwork the projections of the courses should never be more than $\frac{1}{4}$ brick ($2\frac{1}{4}$ inches), in order that each back joint may be kept well within the last course. When great strength is required, the courses may project only $1\frac{1}{8}$ inch or $\frac{1}{8}$ brick.

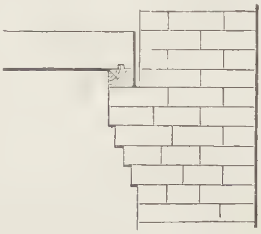


Fig. 119.
Corbel in Brickwork.

Stone corbels are often used in brickwork (see Fig. 296).

String Courses in brick walls are frequently of clay-ware or stone, but are sometimes formed with the bricks themselves, by projecting two or three courses from the face of the wall. The upper surface of the projecting portion of a string course should be weathered or splayed to throw off the wet.

Sometimes a fillet of cement is used to effect this.

Strength of Brickwork.—Brickwork under certain circumstances may be subject to transverse and shearing stresses (see Part IV.), but the more ordinary condition of stress is that of compression, either as in the walls of a building carrying their own weight in addition to that of floors and roof, or as isolated piers supporting heavy loads. Experiments on brick piers have shown that their strength is dependent not only on the crushing strength of the bricks used, but also on the composition of the mortar, the proportion of height of pier to least dimension, and other conditions.

Particulars of these experiments will be found in Part III., pp. 115-121.

Chapter III.

MASONRY.

WALLING.

Classification.—Masonry may be classed either as "ashlar" or "rubble."

Ashlar is built from large blocks of stone, carefully worked, while *rubble* is composed of small stones, often irregular in shape, and in the roughest description, hardly worked at all.

Between these two there are many gradations.

Different kinds of masonry are sometimes combined. Thus, walls are built with ashlar facing and rubble backing, or with stone facing and brick backing.

Without proper precaution this may lead to defective construction, the consideration of which is entered upon in Chapter IV.

General Remarks.—Masonry requires more skill to build than brickwork. The bricks, being all of the same size, are laid according to regular rules, whereas with each stone judgment is required in order that it may be laid in the best way.

The more nearly the work approaches ashlar the more regular are the stones, and the more easily are they built.

Natural Bed.—As a rule every stone in ordinary walls and arches should be laid upon its "*natural bed*,"—that is to say, the bed upon which it rested when originally formed, should now be perpendicular to the principal pressure upon it.

When a stratified stone is placed vertically, and so that the layers of which it is composed are parallel to its face, they are apt to be split off in succession by the action of the weather. Moreover, a stone in this position has not so much strength to resist crushing as it has when placed on its natural bed.

In a cornice with overhanging or undercut mouldings the natural bed should be placed parallel to the side joints, for if placed horizontally layers of the overhanging portions will be liable to drop off. There are other exceptions to the general rule which occur in more elaborate work; also some dependent upon the nature of the stone, the quarry, etc. These will be noticed in Part III.

Precautions in Building.—Great attention should be paid to the

bond in all kinds of masonry. On the face the vertical joints should break upon every stone, no straight joints being allowed.

The bond across the thickness of the wall is of still greater importance, either "thorough bonds," extending from one face to the other, should be inserted at regular intervals, or "headers" should cross each other alternately from opposite sides, extending inwards about $\frac{2}{3}$ the thickness of the wall.[1]

Some authorities prefer headers to thorough bonds in walls more than 3 feet thick, because the interior of the wall settles down rather more than the sides, leaving a hollow, so that a thorough bond stone would be unsupported in the middle, and might be broken. Another reason against long bond stones is, that there is danger of the beds not being even throughout, in which case the pressure comes upon a few points, and the stone is liable to break in two.

Masons are very apt to build up the sides of a wall separately, filling in with small stuff, or even dry packing. The wall thus consists of two thin slabs, united only by the thorough bonds.

This should never be allowed. The stones should be made to cross from opposite sides of the wall, and overlap as much as possible, so as to assist the bond stones in giving transverse strength to the wall. The interior of walls of every description should be solidly filled in, every stone being bedded in mortar, and all interstices flushed up.

Thorough bonds should always be amply thick enough to carry the weight above them, as, if broken, the fracture forms a dry joint, and they become worse than useless.

The width of bond stones may be about $1\frac{1}{2}$ times their height, and the aggregate surface shown by their ends, on each face of the wall, should be from $\frac{1}{8}$ to $\frac{1}{4}$ of the area of the face. Care should be taken that each bond stone is of sufficient sectional area throughout its length.

Thorough bonds present an advantage over three-quarter headers, inasmuch as they can be traced in the work, and therefore cannot easily be omitted by the mason without detection, but they are more expensive, as each must be cut to a length exactly equal to the thickness of the wall, and, moreover, they are apt to conduct damp through the wall.

The practice of leaving the ends of thorough bonds sticking out beyond the wall, and knocking them off afterwards, should not be allowed, as it shakes and injures the masonry.

Thorough bonds should not be placed directly over one another, but chequer-wise, so that each bond stone in any course is over the centre of the interval between two in the course below.

In work built up to courses the bond stones are generally specified to be from 4 to 5 feet apart in each course, and they should be placed in position before the course is built.

Large and sound stones should be selected for the quoins, jambs, etc., so that the angles may be well bound together, which materially strengthens the building.

[1] Sometimes called "*dog's-tooth bond.*"

Iron work should not be built into stone in positions where, by rusting, it might disfigure the face with stains, or in such a way that it may burst the stone, by its increase in bulk during oxidation or by its expansion and contraction from heat and cold.

Ashlar Masonry is built with blocks of stone very carefully worked, so that the joints generally do not exceed $\frac{1}{8}$ or $\frac{1}{10}$ inch in thickness.

The size of the blocks varies with the nature of the stone, and must also be regulated according to the facilities that are available for moving and setting them.

Rule for the Proportion of Stones.—"In order that the stones may not be liable to be broken across, no stone of a soft material, such as the weaker kinds of sandstone, and granular limestone, should have a length greater than 3 times its depth. In harder materials, the length may be 4 or 5 times the depth. The breadth in soft material may range from $1\frac{1}{2}$ times to double the depth: in hard materials it may be 3 times the depth."—*Rankine.*

Ashlar is the most expensive class of masonry built, and depends for its strength upon the size of the stones, the accuracy of the dressing, and the perfection of the bond; but hardly at all upon the quality of the mortar.

Mortar.—The mortar used for the superior descriptions of ashlar must be very fine and free from grit. The outer portion of the joint, about $\frac{3}{4}$ inch in from the face, is generally filled with putty, as described at p. 42—either that formed from lime and water, and known as "plasterer's putty," or in some districts white lead is added to it.

Faces, Beds, and Joints.—The faces of ashlar stones may be polished, worked in any way or left rough; a drafted margin [1] is frequently run round them, but this depends upon the style of the work.

The joints, though very carefully dressed, should not be too smooth, otherwise their surfaces will afford no key for the mortar, nor offer sufficient resistance to the sliding of the stones.

It is important, however, that the surfaces of each stone should be "out of winding," that is true planes; and that they should be square to one another.

Great care must be taken that bed joints are not worked hollow. This is sometimes done in order to show a very fine joint on the face without the trouble of carefully dressing the whole bed. It leads to the entire weight

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[1] "Drafted margins," or "drafts," are narrow strips or borders chiselled round the edges of the faces of a stone to enable it to be set with accuracy, and in some cases to improve its appearance.

being thrown on to the point in front (C in Fig. 120), and a "*spall*" or piece, S, is splintered off; the stone is then said to be "*flushed*" at this point.

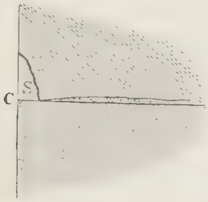

Fig. 120. *Hollow bed Joint.*

Fig. 121. *Slack bed Joint underpinned with a Spall.*

With the same object of saving labour, the back of the joint is sometimes worked slack and underpinned, as in Fig. 121. The stone is then supported only at the front and back, and liable to break in the middle, as shown.

Where bed joints are worked convex, the pressure that comes upon them is concentrated upon a single point, and leads to crushing or splitting of the stone.

Where the beds and joints are not carefully worked throughout, they should be so for at least 6 inches in from the face.

Flushed joints are particularly likely to occur with stones that are not laid on their natural beds.

They may be guarded against by raking out the mortar to a depth of an inch or two from the edges of the stones, pointing up again when the work has settled, or by chamfering [1] them off as in the quoins in Figs. 122, 123.

In any important work with fine joints, especially in columns, sheet lead is often laid between the stones, which is intended to yield to the irregularities on the bed and to distribute the pressure.[2] The lead should extend only to within about an inch of the outer edges of the stones, so as to leave a clear space between them, and prevent them from bearing upon one another and flushing.

Bond.—The general directions with regard to bond, given at pp. 2, 39, are easily followed in ashlar masonry.

The lap or bond given to the stone varies, according to the nature of the work, from once to once and a half the depth of the course; and it should under no circumstances be allowed to be less than from 4 to 6 inches, according to the size of the stones.

The best bond for ashlar consists of headers and stretchers [3] alternately on the same course—an arrangement similar to Flemish bond in brickwork (see Fig. 50). It is however seldom executed in this way on account of the expense of so many headers.

In setting ashlar, the stone should first be placed in position dry, to see if it will fit, the upper surface of the last course should then be thoroughly cleaned off and wetted: on this a bed of mortar is evenly laid, with a strip

[1] *Chamfering* consists in taking off the rectangular *arris* or sharp angle of a stone, so as to form a flat strip, an inch or so in width, at an angle of 45° with the face.

[2] Mr. Kirkaldy has proved by experiment that the effect desired is not produced, and that the practice is a bad one.

[3] These are, properly speaking, bricklayers' terms, but may be, and often are, used for convenience with regard to masonry. Sc. *Inbonds and Outbonds.*

of lime putty about $\frac{3}{4}$ inch wide along the front edge. The block, with its bed joint well cleaned and wetted, is then laid evenly in its place, and settled by striking it with a mallet.

Ashlar walling is described as "coursed" or "random."

COURSED ASHLAR walls consist of blocks of the same height throughout each course. This is the most usual form in which ashlar is built, but it is the most expensive, as great waste of material and labour is occasioned by reducing all the stones to the same height.

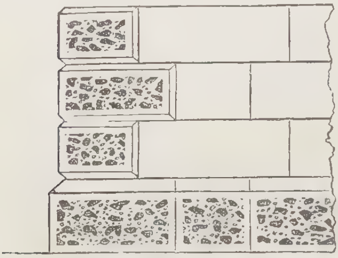

Fig. 122. *Ashlar Walling with chamfered and rusticated Quoins and Plinth.*

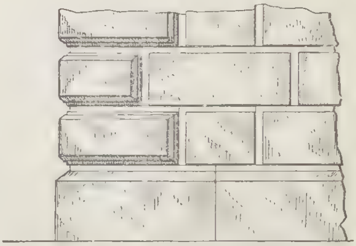

Fig. 123. *Ashlar Walling with rebated Joints and Moulded Quoins.*

Fig. 122 shows coursed ashlar walling, with chamfered and rusticated quoins and plinth, and Fig. 123 ashlar with rebated joints and moulded quoins.

RANDOM ASHLAR walls are built with rectangular blocks of all sizes and dimensions. This is a cheaper kind of work, as it enables a larger proportion of the stone as quarried to be used without waste in reducing to fixed sizes; but it is generally considered inferior in appearance to coursed work, and is very seldom adopted.

Rubble[1]—GENERAL REMARKS.—There are several kinds of rubble work, each known by a technical name, depending upon peculiarities in the arrangement of the stones, or in the work upon them.

Some points common to all rubble walls will be considered before the different classes of work are described.

As the beds and joints in rubble work are generally not carefully dressed, the strength of the walling depends greatly upon the mortar, which should be of the best quality.

Considerable skill is required on the part of the builder, who has to work in stones of irregular shape in the most advantageous manner. Such stones should, where possible, be placed on their widest beds so that they may not be crushed, or act as wedges, and force out the adjacent work.

[1] Sc. *Ruble.*

Headers or thorough bonds should be regularly provided, of sufficient thickness to resist fracture. Their numbers, size, and position will be roughly determined by the considerations mentioned in discussing bond stones at p. 39.

In the inferior classes of rubble the spaces between the stones of irregular shape must be packed in with "spalls,"[1] and in all cases the "hearting" or inside of the wall should be carefully filled with as large fragments as possible, well bedded in mortar.

All stones in rubble walling should be placed on their natural beds, and as nearly horizontal as the class of work will allow.

The names given to different classes of rubble work vary greatly in different parts of the country.

The following must therefore be taken merely as a general guide, not as a rigid classification adapted to all localities.

Random Rubble (*uncoursed*).—In common random rubble work the beds and joints are not dressed, projecting knobs and corners are knocked off with the hammer, and the stones lie together at random, the interstices being filled in with small spalls and mortar. No attention is paid to courses, though each stone should be approximately horizontal.

This is a most inferior description of walling, unless it is executed with very good mortar, upon which its strength greatly depends. It requires

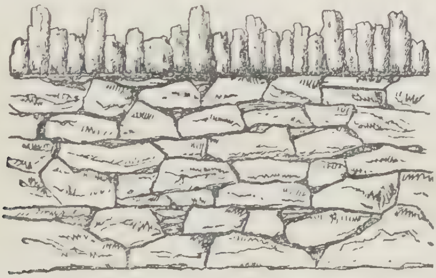

Fig. 124. *Random Rubble Walling with Rubble-on-edge Coping.*

considerable skill to build such a wall properly. The bond should be carefully attended to, and though it is almost impossible in the roughest work to break joint on every stone, yet long vertical straight joints should not be permitted. The external appearance and method of building random rubble depends entirely upon the nature of the material, which may vary in every gradation from rough intractable boulders to stones with a beautiful cleavage and natural beds nearly as smooth and even as if they had been carefully worked.

Random Rubble built in Courses.—In this walling the work is

[1] Pieces of broken stone. Sc. *Shivers.*

brought to a level throughout its length at about every 12 or 14 inches in height, so as to form courses of that depth.

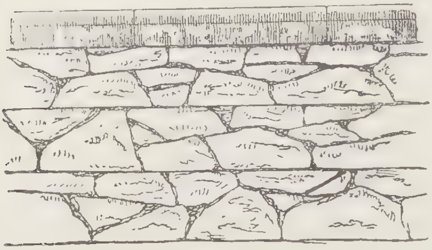

Fig. 125.
Random Rubble Walling built in Courses.

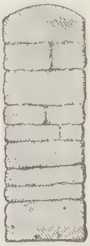

Fig. 126.

The work in each course is built random, and may consist of two, three, or more stones in depth, pinned in with spalls as before described. The better the work the fewer the spalls.

Squared Rubble[1] (*uncoursed*) has the joints and the angles of the faces neatly squared with the tools locally used. The beds are horizontal, and the side joints vertical.

This description of rubble is peculiarly adapted for such stones as have a fine cleavage, affording bed joints which require little or no working. The thickness and length of the stones and style of work depend greatly upon the material. Some quarries furnish a larger proportion of large stones than is shown in the sketches, and others consist nearly entirely of thin beds.

In this kind of walling the work is sometimes allowed to run for short lengths into courses, these being frequently broken by high stones reaching from one course into the next above. Such work is often called "*Irregular coursed rubble.*"

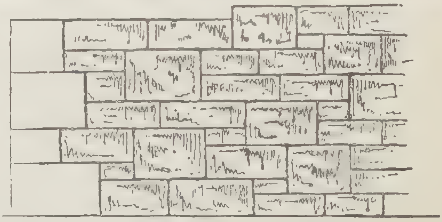

Fig. 127. *Squared Rubble Walling with Ashlar Quoins.*

Squared Rubble built in Courses is squared rubble brought to a level course throughout its length at every 10 or 14 inches in

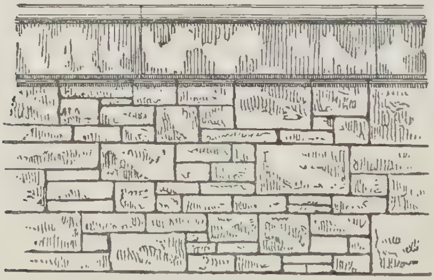

Fig. 128.

Fig. 129.

Squared Rubble Walling built in Courses, with Saddle-back Coping with Roll.

[1] Sc. "*Snecked ruble*"—the abrupt breaks in the bond being called "snecks."

height: it is sometimes known as "*irregular coursed rubble brought up to level courses.*"

In squared rubble straight vertical joints are often allowed, so long as they are not more than a foot or so in height, for random work, and not more than the height of a course in work built in courses.

In one variety of this rubble the side joints are left splayed to save labour.

Coursed Header Work is rubble similar to that shown in Fig. 128, except that the headers or bond stones are each of the full depth of the course in which they occur, the intervals between them being filled in with smaller stones.

COURSED RUBBLE, or *Regular Coursed Rubble*, consists of stones laid in courses, every stone in the same course being of the same height; the height of the courses may, however, vary from 4 to 8 inches.

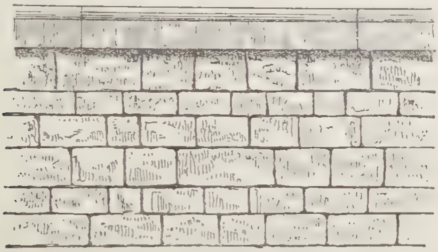

Fig. 130.

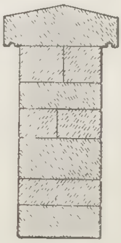

Fig. 131.

Coursed Rubble Wall with Coping.

With some kinds of stone found in thin layers and having good natural beds, there is a greater distinction made between the thickness of the courses, three or four courses from $1\frac{1}{2}$ to 3 inches thick, alternating with one or two courses from 4 to 5 inches thick, as shown in Fig. 146.

DRY RUBBLE is rubble (generally "random") built without any mortar. It is the cheapest form of work, but requires considerable skill on the part of the builder.

FLINT RUBBLE is composed of flints and pebbles—or "*popples*"—laid in mortar. It forms a kind of concrete depending upon the mortar for cohesion. Great care must be taken to keep it dry and safe from the action of frost.

The interior of the wall is sometimes filled in with chalk, broken bricks, pebbles, etc.

Walls may be built with the "*rough*" flints just as they are dug out from the chalk, or they may be "*random*"—that is, with the flints irregularly broken.

The stones are frequently "*polled*" or split, and the fractured surfaces placed flush with the face of the walling. The beds of the flints must be

pinned up with fragments, so that their upper surfaces are level, or wet will be led into the wall, and long flints must be used as through stones.

Small sharp pieces or "gallets" of flint are sometimes stuck into the mortar joints, in which case the work is said to be "*galleted*."

When the stones are split and roughly squared the walling is called "*snapped flint work*."

RUSTIC OR POLYGONAL RAGWORK is built with Kentish Rag or similar stone, in small pieces, which are knocked into irregular shapes and dressed with the hammer, either roughly to fit one another, the interstices being filled in with spalls, which work is called "*rough picked*"; or with care and accuracy, the stones being carefully worked to regular polygonal forms, in which case no spalls are allowed, and the work is said to be "*close picked*."

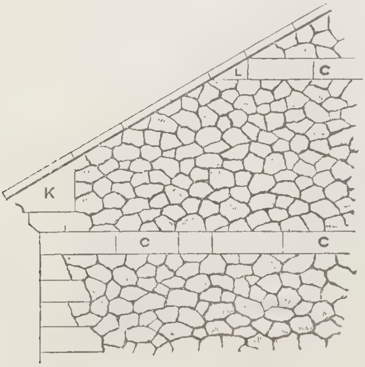

Fig 132. *Polygonal Kentish Ragwork.*

Walling of this material is sometimes backed in with "hassock," a soft stone found in layers with the rag, and unfit for external work.

LACING COURSES.—Walls such as those built with flints, or other small stones, having but little bond in themselves, are frequently strengthened by building in with them lacing courses, consisting of horizontal bands either of ashlar, coursed rubble, or brickwork (see C C, Fig. 132).

Block in Course, or *Blocked Course*, is a name given to a class of masonry which occupies an intermediate place between ashlar and rubble.

The stones are of large size, so that they must be procured in blocks, not as rubble; but the beds and joints are only roughly dressed, and so the work cannot be described as ashlar.

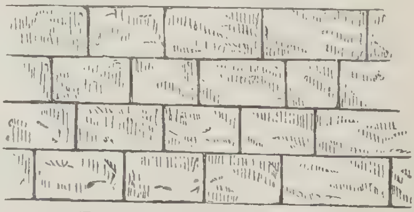
Fig. 133. *Block in Course.*

This kind of walling is sometimes known as "*hammer-dressed ashlar.*" It is used chiefly in engineering works, and seldom, if ever, for ordinary buildings.

Ashlar Facing.—The expense of ashlar masonry prevents it

from being used throughout the whole thickness of a wall, except in works of great importance and solidity.

It is therefore frequently used merely as a facing, and is backed in with rubble or brickwork; and by some the term "ashlar" is used to apply only to such a facing, not to a solid wall.

Such a construction may, without precaution, be open to objections, which are pointed out in Chapter IV.

STONE ARCHES.

The names of different forms of arches and their parts are given at pages 4 and 5.

Cut Stone or Ashlar Arches.—In block stone arches (see Fig. 3, p. 4) the voussoirs are always cut to a wedge shape.

The curve of the arch having been set out full size on a board, and the number of stones and thickness of arch having been decided, the intrados is divided into as many parts as there are stones, and lines drawn from the centre through these points, till they cut the extrados, give the sides of the voussoirs.

By the aid of the diagram thus laid out, patterns or templates in wood or zinc are made for the use of the stone-cutters, who are thus enabled to work the stones to the required forms.

In setting stone arches the space to be occupied by each voussoir—not forgetting the thickness of the joints—is carefully laid out on the centre,[1] and the position of the stones checked as they are set.

The stones should be set alternately on each side of the centre, so as to weight it evenly.

The keystone should be carefully fitted at the last before it is set, and driven gently into its place with a few taps of a mallet.

When the arch is so long in plan that one stone cannot extend through from front to back, the work must be built with a regular bond along the soffit. The voussoirs are kept at the same width all through, but of different lengths, so as to break the bond in the length of the arch.

Rubble Arches are built of smaller stones, generally roughly dressed to the wedge shape.

They should be built in mortar of good quality, as they depend greatly upon its coherence for their strength.

JOINTS AND CONNECTIONS.

Sometimes greater security is required for joints than that afforded by the adhesion of the mortar and the weight of the stone.

[1] The *centre* is a framework of wood having a curved upper surface, and is arranged so as to support the stones of the arch while it is being built (see p. 158).

Cases of this are likely to occur in heavy copings on inclined walls—in masonry exposed to severe blows from the sea, and with detached stones not kept in place by surrounding masonry.

There are several methods of giving additional strength to the joints of masonry, the most common of which will now be considered.

Metal Connections.—With regard to metal connections it may be said, once for all, that copper or bronze make the best, as they do not oxidise to any great extent. If iron is used, it should be well protected from air or moisture, and also painted or galvanised, or it will rust, increase in bulk, and split the stones. All metals are liable to do the same, more or less, by their expansion and contraction under intense heat and cold.

Dowelled Joints are formed with slightly tapering pins, or "dowels," which fit into holes made in the stones opposite to one another (see Fig. 134).

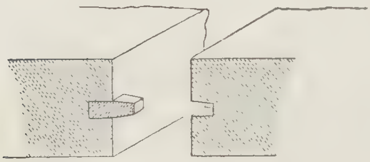

Fig. 134. *Horizontal Dowel.*

The dowels may be rectangular, square, or circular, in section, and formed of hard stone, slate, or metal.

They are sometimes placed vertically in a joint, as in Fig. 135, the upper part of which shows half the hole cut for the dowel, and the lower part shows the part of a dowel in position, or they may be double dovetail in plan, and placed horizontally, as in Fig. 136.

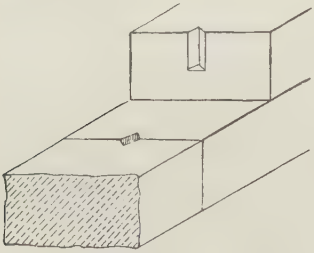

Fig. 135. *Vertical Dowel.*

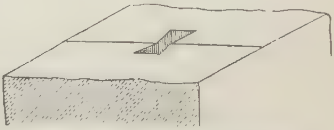

Fig. 136. *Dovetailed Dowel.*

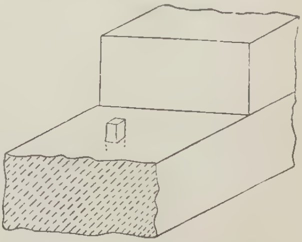

Fig. 137. *Bed Plug.*

Dowels are sometimes made to fit very loosely, and run with lead, cement, or brimstone, but accurate fitting is better.

A short vertical dowel in the centre of a stone is sometimes called a "*bed plug*" (see Fig. 137), and

is useful for copings or heavy stones, built on an inclined ramp or gable, and for many other purposes.

Joggled Joints are similar to dowelled joints, except that the joggle or projection is a part of the stone instead of being detached like the dowel. To leave such a projection in working the stone would cause great labour and waste of material, and it is seldom done in practice.

The word "joggle" is often applied by masons to dowels, and to all sorts of joints in which any portion of one stone enters the other.

Grooved and Tongued Joints.—In these a prolonged joggle or tongue is worked upon one stone, and fits into a groove in the other. A somewhat similar joint is used in joinery. See Part II.

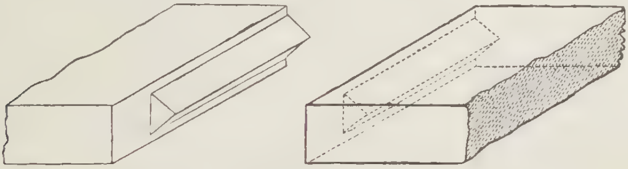

Fig. 138. *Grooved and Tongued Joint.*

A modification of the joint, in which the groove and tongue, or joggles, are angular, is shown in Fig. 138.

A more economical joint is formed by cutting grooves in both the stones, and inserting a metal tongue.

Metal Cramps should be used as little as possible, for they are very liable by their rusting and expansion to destroy the work in which they are bedded; when used they should be placed in a channel cut in the upper surface of two stones, having dovetail-shaped sinkings at the ends, into which the turned-down and jagged extremities of the cramp may fit.

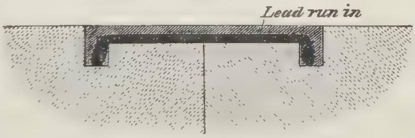

Fig. 139. *Metal Cramp.*

The channel should be deep enough to conceal the cramp, and is filled in with lead or cement to protect the latter from oxidation.

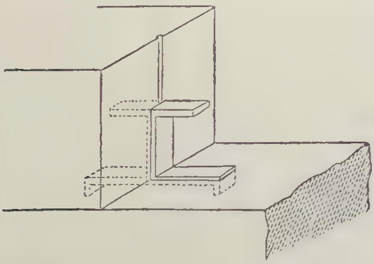

Fig. 140. *Combined Cramp and Dowel.*

In old buildings of an important character the combined cramp and dowel shown in Fig. 140 has been adopted, but it would not be used in these days.

Lead Plugs are formed by pouring molten lead into plug-holes (generally dovetail-shaped) formed in the stones, as shown in section Fig. 141. The holes slope downwards, in order that the lead may run at once into the ends and corners so as to fill them completely.

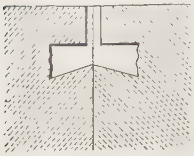

Fig. 141. *Lead Plug.*

Rebated Joints between two stones are made by taking a check out of the end of each, so that they may overlap each other. They are exactly similar to those used in joiners' work, and shown in Part II.

An illustration of their use is given in Fig. 146.

Tabled Joints are those in which a wide projection is left on one stone, fitting into an indentation cut in the other. Joints formed like this are often said to be joggled. They involve a waste of material, and are used only for heavy work subject to concussion, such as the walls of lighthouses.

Special Joints of elaborate form, of dovetail form horizontally and sometimes vertically also, are used in lighthouses and in some other works intended to resist the action of the sea, but they cannot here be described.

DRESSINGS.

Quoins are the corner stones of buildings. They play an important part in binding the walls well together at the angles, and are often made conspicuous by better or more pretentious workmanship.

In heavy masonry they frequently project an inch or two from the face of the wall (see Figs. 122, 123), and the margin is either "sunk drafted,"[1] moulded, or chamfered, the face being boldly worked, "rusticated" (see Fig. 122), or left with the rough "rock" or "quarry face."

The quoins of rubble walls are often in ashlar, of a better stone, with close joints—the face being either left rough or worked according to taste.[2]

In some descriptions of work the quoins are made of the exact height of the courses of rubble, being first set as gauges, to which the latter are levelled; but frequently the quoins are quite independent of the rubble, and irregular in every way—no two stones are of the same size or shape, and the joints abutting against the rubble are left rough and not kept vertical (see Figs. 132, 143). Stone quoins to brick walls should be the exact depth of a certain

[1] *Sunk draft* is a margin, as described at page 40, sunk below the general surface of the stone.

[2] The different methods of working the faces of stones, and the operations of stone cutting, are not included in this work.

number of courses, so that they may readily bond in to the brickwork.

Second Quoins, such as those shown at *s s* in Fig. 146, are sometimes used, where the ordinary quoins are small, in order to give additional strength to the angle of the wall. The stretchers may be doubled as well as the headers.

Window Sills (see page 10) should be worked smooth, rubbed, and weathered,[1] so as to get rid of the water as quickly as possible, and throated,[2] to prevent it from falling on the wall below them.

An ordinary window sill is shown in elevation in Fig. 94, and also in Fig. 15 and others. The corbels *y y*, shown below the sill in the latter case, may be required for support of very projecting sills, but are often added only for ornament. The most usual form of section is given in Part II.

A groove should be cut along the centre of the upper surface of the sill, to correspond with one in the bed of the oak sill of the window frame, into which a metal water bar or tongue is inserted, to prevent wet from getting in through the joint.

With the same view of preventing the entrance of wet, the stone sill is sometimes checked out to receive the oak sill, but this is an expensive construction seldom adopted.

Different methods of finishing the ends of sills are shown in Fig. 94, and in the chapter on Joinery, Part II.

Window and Door Jambs.—In the commoner buildings these may be of rubble; but they are more frequently of cut stone even in rubble walling. They are generally formed with reveals, as explained at page 10, the thickness of stone in front of the check, or sinking for the frame, varying from 6 to 12 inches.

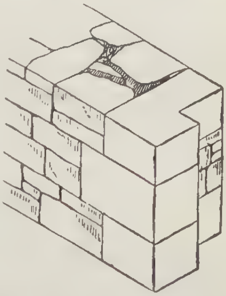

Fig. 142. *Stone Jamb with Reveal.*

It is important to secure a good bond in the jambs of all openings; every header should go right through the thickness of the wall, the alternate stones stretching along the face.[3]

[1] *Weathering* is dressing off the upper surface of a stone to a slight slope, in order that the rain may not rest upon it.

[2] *Throating* is cutting a groove or *throat* on the under side of that part of a stone which projects over a wall, in order that the water trickling over the face of the stone may be stopped before it reaches the wall.

[3] Sc. *Inbonds and Outbonds.*

The stones forming the jambs—("jambstones"[1]) may be chamfered, moulded on the outer angles, or ornamented in different ways to suit the style of the building.

To save expense, architraves[2] or other ornamental mouldings are often worked separately in thin strips, or stuck up on edge round the door or window opening to be ornamented.

In other cases the jambs each consist of one long stone on end, the height of the opening, with the architrave worked upon it.

Lintels—Window and Door Heads.—Stone lintels may be used to cover any narrow opening in a wall.

When intended to form a "head" to a door or window opening, the lintel rests on the jambs, and the under side in some cases is checked out so as to form a reveal for the head of the frame.

It is better, however, that the under side or "soffit" of the lintel should be left flush throughout, a wood lintel with relieving arch, concrete beam, or flat arch, supporting the wall behind it, being kept higher than that of the stone lintel, so that room is afforded for the head of the wood frame (see Part II.)

It is often advisable to relieve the stone lintel of the weight of the wall above it. This may be done by a relieving or dis-

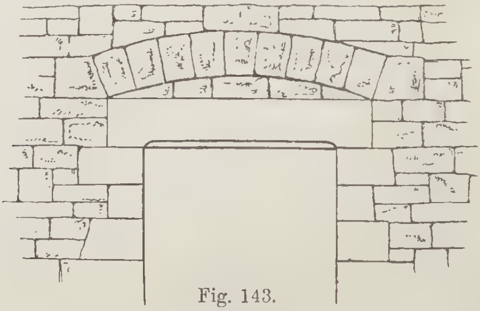

Fig. 143.

Stone Lintel with Relieving Arch.

charging[3] arch, which either forms a feature in the elevation, as in Fig. 143, or if that be objectionable, the walling above may be formed in a sort of flat arch without being conspicuous (see Part II., chapter on Joinery).

When a discharging arch is used, it is sometimes made of the

[1] Sc. *Rybates.* The inner rough stone sometimes used at the back of the stretchers instead of rubble is called a *Scuntion.*

[2] *An Architrave* is an ornamental border formed round an opening such as that for a door or window.

[3] Sc. *Saving arch.*

same span as the opening, so that it rests upon the ends of the lintel instead of being just clear of them as shown in the figure.

The "*core*," or portion between the soffit of the relieving arch and the top of the lintel, should be left out until the whole work has taken its bearing, or the settlement of the arch may cause the core to bear upon and to break the lintel.

String Courses (see p. 9) should, as a rule, extend well into the thickness of a wall to give it strength.

They should, if of sufficient projection, be weathered and throated.

Stone string courses in brickwork should be of the exact height of a certain number of courses of bricks (see Fig. 144), otherwise they will necessitate bricks being cut, or upset the bond.

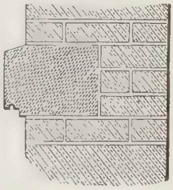

Fig. 144. *Stone String Course.*

The stones are sometimes united to one another by metal cramps, so as to form a continuous band round the building.

Corbels are stones projecting from a wall, generally in order to form a support, as in Fig. 296.

When the weight to be borne is very great, and in other cases (see p. 9), several courses may be corbelled or gathered over, as already described.

Eaves Courses (see p. 8).—An example of a stone eaves course arranged so as to support an iron gutter is shown in Fig. 411.

Copings[1] (see p. 7) should be in as long stones as possible, to avoid joints which admit the wet.

The upper surface should be weathered, and horizontal copings should be throated.

The stones of an ashlar coping may be cramped or dowelled together, or united by lead plugs.

On a steep ramp or gable it is necessary to dowel the coping to the wall to prevent it from slipping down the slope, or the same object may be attained by working the coping with a horizontal bed, and of such a depth as to enter the wall, as shown at L in Fig. 146. This is not, however, usually done with every stone, but only at intervals in the length of the coping.

A common construction is to cut the backs of these stones vertically downwards from the point *a*, so that they are triangular in section (see Fig. 132), but this is not so good a form as that shown at L in Fig. 146; especially in a gable of steep pitch, as the

[1] Sc. *Copes.*

height of the stone would be greater than its base, and it would have a tendency to tilt over when the thrust came upon it.

The joints of inclined copings may be rebated as shown in Fig. 146, so that as the wet which gets in at the top of the joint cannot flow upwards in the rebate, it is prevented from entering the wall.

SADDLE-BACK COPING.—Fig. 145 is the section of a saddle-backed coping; the top, instead of being formed by two plane surfaces as shown, is frequently rounded.

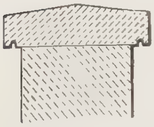

Fig. 145. *Saddle-back Coping.*

PARALLEL COPING is one of which the upper and lower surfaces are parallel. Such a coping may be used for gables or ramps where it is laid at an inclination, and therefore a sloping transverse surface to throw the water off is not necessary. A coping[1] of this kind is shown in section in Fig. 416.

FEATHER-EDGED COPING.—Fig. 348 shows this form of coping on a parapet wall. It is weathered in one direction only, so as to throw off the water into a gutter on the inside.

COPINGS FOR RUBBLE WALLS may be formed with long stones laid horizontally on the top, and either left rough, or worked; or they may have a rough coping consisting of flat stones on edge. These are sometimes alternately high and low, so as to present a rugged and picturesque appearance (see Fig. 124, p. 43).

The coping of a pier or column is called the *Capital*, that of a chimney is called the *Cap*.

Skew Corbel.[2] KNEELER or KNEE STONE (K, Fig. 132) is the stone at the foot of a coping on a gable or ramped wall. It is sometimes cut off vertically downwards from the point *a*, but such a construction is objectionable for the reasons given at p. 53 with regard to the stone L. It is

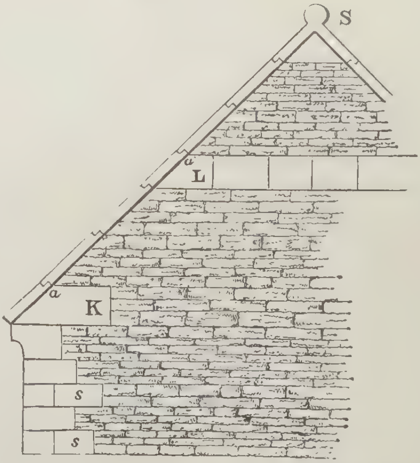

Fig. 146. *Showing Apex-stone S, Kneeler K, and Second Quoins s s.*

[1] Sc. A coping in this position is called a *skew*. [2] Sc. *Club-skew.*

better that the kneeler should tail into the wall as shown at K in Fig. 146, so that it has a base much greater than its height, and the rubble above it helps to keep it in its place.

Saddlestone is that forming the apex of a gable; also called *Ridgestone* and *Apex-stone.*

Cornices (see p. 8) should project well, so as to protect the wall from wet, and should be weathered and throated.

It is important that sufficient of the cornice should rest on the wall to balance the projecting portion, or it will press unfairly on the front of the wall and be unstable.

Sometimes the stones are left a little high at the joints between them, as at x, Fig. 147. This is called "*saddling the joints,*"[1] and is intended to throw the water off them, but involves much expense in extra labour.

The joints between the stones of the cornice, and also those of the blocking course or parapet above, are often secured by lead plugs (see p. 50).

The cornice may itself form the uppermost member of the wall, or it may be surmounted by a blocking course, by a parapet wall, or by a balustrade.

Cornice.—In the first case a raglet[2] may be required to receive the flashing or apron of a lead gutter at the back of the cornice, as shown in Fig. 147, or the gutter may be formed in the stone itself, as in Fig. 413, care being taken to line the hollow with lead or cement if the stone is at all porous. Sometimes the whole upper surface of the cornice is covered with lead.

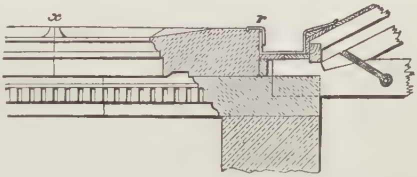

Fig. 147. *Stone Cornice. Sectional Elevation showing Saddled Joint at x.*

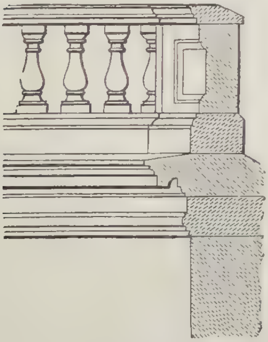

Fig. 148. *Cornice and Balustrade.*

Cornice and Blocking Course.—This may be seen in the section Fig. 435. The top of the blocking course is generally grooved to receive the lead of the gutter or apron, or the latter may be allowed to extend over it.

Cornice and Balustrade.—This is shown in Fig. 148. The

[1] Sometimes called "*water-jointing.*"

[2] See p. 229.

small columns are called balusters, and are divided into groups by solid panelled blocks called "*pedestals.*" In Fig. 148 a half pedestal is shown in elevation at the angle.

CORNICE AND PARAPET.—This is a similar construction to that last mentioned, except that the cornice is surmounted by a solid wall. See Fig. 348 and others.

CHAPTER IV.

BRICKWORK AND MASONRY.

(Continued from Chapters II. and III.)

THIS chapter will contain some notes on a few points connected with Brickwork and Masonry, which have been briefly alluded to in the preceding chapters.

COMPOUND WALLS.

It has already been said that uniformity of construction in walling of any description is of great importance.

All walls must be expected to consolidate and settle down when weight comes upon them, but so long as they settle equally no injury is done; *inequality* of settlement, however slight, is dangerous, and produces unsightly cracks in the masonry.

Such results may arise from want of uniformity in construction, while another evil may be involved, viz. instability when exposed to the action of fire. With regard to this, Captain Shaw, the late Chief of the London Fire Brigade, says, "The walls of a most pretentious and imposing building, of sufficient thickness, and apparently constructed of sound stones, are found to crack at an early stage of a fire, and perhaps to fall down altogether, and then it is discovered that they have been only a deception, having been constructed externally of stone and internally of brick." [1]

It will be as well to notice two or three forms of composite walls, in order that their structure and defects may be described.

In all compound walls the backing should have joints as nearly as possible equal in number and thickness to those in the face, so that the back and front may settle down under pressure to the same extent; if not, the joints should be in cement or quick-setting mortar, in order that they may become consolidated before any pressure comes upon them.

Evils of Facing with superior Bricks.—It is a common practice, especially in using single Flemish bond, to build the face

[1] *Fire Surveys*, by Captain Shaw, C.B.

work with better bricks, and with thinner joints, than the backing. This leads to unsound work, and should not be allowed.

In such cases, on account of the joints of the backing being thicker than those of the face work, the courses will not be of the same depth in front and back. For example, it may require eight or nine courses of the face to gain the same height as six or seven in the backing (see Fig. 149), and it is only when they happen to come to a level, as at *aa* (once in every eight courses or so), that headers can be introduced. Even the few that can thus be used are liable to be broken off by inequality of settlement, caused by the difference in the thickness of the joints.

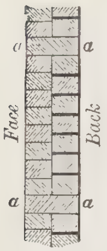

Fig. 149.

This may be partly remedied by using thinner bricks in the backing, so as to have the same number of joints in face and back; but even then the difference in thickness of the joints in facing and backing tends to cause unequal settlement, unless the work is built in very quick-setting mortar which will harden before any weight comes upon it.

A further result of this practice is that, in order to economise the more expensive face bricks, dishonest bricklayers will cut nearly all the headers in half, and use "false headers" throughout the work, so that there is a detached slice, $4\frac{1}{2}$ inches thick, on the face, having no bond whatever with the remainder of the wall.

Brick Ashlar.—This is a name given to walls with ashlar facing, backed in with brickwork.

In this system of construction, frequently adopted in modern buildings, the coarser and more numerous joints in the brick backing as compared with the finer and fewer joints in the ashlar, may, without precaution, give rise to the evils of unequal settlement. In practice, however, the use of bricks of superior quality set in Portland cement mortar will be found to obviate the difficulties referred to, if the work is carefully carried out.

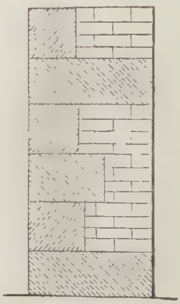
Fig. 150.

In building such work the ashlar stones should be of heights equal to an exact number of courses of the brickwork, in order that they may bond in with it; the stones should be properly square throughout, with the back joints vertical, so as to leave no vacuities between the facing and the brickwork, for these could

not be properly filled in without the expense of cutting bricks to fit the irregularities.

Rubble Ashlar consists of an ashlar stone face with rubble backing (see Fig. 151), and is subject, even to a still greater extent than brick ashlar, to the evils caused by unequal settlement.

To avoid these evils, the stones and joints of the rubble backing should, as before mentioned, be made as nearly as possible of the same thickness as those in the ashlar facing, or, if the joints are necessarily thicker, there should be fewer of them, so that the total quantity of mortar in the backing and face may be about the same. This can seldom be economically arranged in practice, but it should be remembered that the more numerous and coarser the rubble joints, the worse the construction becomes.

Fig. 151.

The ashlar should be bonded in with "through-stones" or "headers," as previously described; their vertical joints should be carefully dressed for some distance in from the face, and their beds should be level throughout; the back joint and sides of the tails of the stones, may, however, be left rough, the latter may even taper in plan with advantage, and they should extend into the wall for unequal distances, so as to make a good bond with the rubble, the headers from which should reach well in between the bond stones of the ashlar. Through stones may be omitted altogether, headers being inserted at intervals on each side extending about $\frac{2}{3}$ across the thickness of the wall.

Care must be taken that the stones in the ashlar facing have a depth of bed at least equal to the height of the stone. In common work the facing often consists merely of slabs of stone having not more than from 4 to 6 inches bed, with a thin scale of rubble on the opposite side, the interval being filled in with small rubbish, or by a large quantity of mortar, which has been known to bulge the wall by its hydrostatic pressure.

The ashlar facing is in all respects, except those above mentioned, built as described in the section on ashlar, Chap. III., and the backing may be of random rubble done in courses from 10 to 14 inches high, according to the depth of the stones in the facing.

Fig. 151 is the section of a wall 3 feet thick, with an ashlar facing composed of good substantial stone.

PREVENTION OF DAMP IN WALLS.

The importance of keeping moisture out of walls as far as possible need hardly be dilated upon.

In addition to the great importance of a dry building for sanitary reasons, it is also most necessary for good construction; dampness in the masonry soon communicates itself to the woodwork, and causes rot throughout the building, besides which, the masonry itself is not sound, the mortar, unless of good hydraulic lime, or cement, does not set, and is always liable to the attacks of frost.

To give some idea of the quantity of water that the walls of an improperly protected building may contain, and of the evil effects caused by damp, the following remarks are quoted from an official report.[1]

"In England the common bricks absorb as much as a pint or pound of water. Supposing the external walls of an ordinary cottage to be one brick thick, and to consist of 12,000 bricks, they will be capable of holding 1500 gallons or $6\frac{1}{2}$ tons of water when saturated. To evaporate this amount of water would require nearly a ton of coal, well applied. The softer and more workable stones are of various degrees of absorbency, and are often more retentive of moisture than common brick. Professor Ansted states that the facility with which sandstone absorbs water is illustrated by the quantity it contains both in its ordinary state and when saturated. He states that even granite always contains a certain percentage of water, and in the dry state is rarely without a pint and a half in every cubic foot. Sandstone, however, even that deemed fit for building purposes, may contain half a gallon per cubic foot, and loose sand at least two gallons. When water presents itself in any part of such material it readily diffuses itself by the power of capillary attraction, by which, it is observed on some walls in Paris, it ascends 32 feet from the foundations. Walls of such absorbent constructions are subject to rising wet by capillary attraction, as well as the driving wet of rain or storm. To guard against the driving wet on the coast, expensive external coverings, 'weather slates,' are used. But these do not stay the interior rising wet. This wet having to be evaporated lowers temperature. Damp walls or houses cause rheumatism, lower strength, and expose the system to other passing causes of disease."

It is a wise precaution to cover the whole surface of the ground under a dwelling with a layer of concrete, or asphalte, in order to prevent the damp and bad air out of the ground from rising into the building.[2]

[1] *Report on Dwellings in the Paris Exhibition*, by Edwin Chadwick, Esq., C.B.
[2] This is enjoined by the Model Bye-Laws of the Local Government Board.

This precaution is, however, generally omitted because it involves expense; but measures to keep the walls dry are or should be adopted in nearly all buildings intended for occupation by human beings.

The walls of a building are liable to be charged with moisture—

1. By wet rising in them from the damp earth.
2. By rain falling upon the exterior of the walls.
3. By water from the roofs or leaking gutters soaking into the tops of the walls.

Of these evils the first may be prevented by the construction of dry areas or "air-drains" and by the introduction of damp-proof courses; the second may be counteracted by impervious outer coatings or by the use of hollow walls; and the third avoided by the use of projecting eaves with proper gutters—or where parapet walls are used, by an upper damp course.

Air-Drains are narrow dry areas, 9 inches or more in width, formed around such parts of the walls of a building as are below the ground.

They prevent the earth from resting against the walls and imparting to the masonry its moisture, which, rising by capillary attraction, might cause the evils already referred to.

The outer wall of the area should rise slightly above the surrounding ground, so as to prevent the water from the surface from entering the air-drain. Arrangements should be made for keeping the area clear of vermin, for ventilating it, and also for draining off any moisture that may accumulate at the bottom.

In the section Fig. 209 is shown an air-drain 12 inches wide, having a rubble retaining wall, and being covered by flagstones built into the wall and weathered on the upper surface; of these, one here and there is removable in order to give access to the drain. The air-holes shown in the figure ensure the thorough ventilation of the drain and of the space below the floor of the building.

There are several forms of air-drains; the width of the area is often much less than that shown in the figure, and sometimes is so reduced that the arrangement simply amounts to providing a hollow wall. In other examples the outer retaining wall is curved in plan, between the piers, being concave on the inside, by which additional strength is gained and thinner walls may be used. The area is frequently covered by a small quadrant arch turned against the wall, instead of by paving.

In some cases, to avoid the expense of air-drains, the outer surface of the portion of wall below ground is rendered with cement, asphalted, or covered with a layer of slates attached to the wall.

Substitutes for properly built air-drains may be cheaply formed by placing a flagstone in an inclined position against the outside of the wall to be protected.

Wide and open areas are much more expensive, but allow a freer circulation of air, exclude damp more thoroughly, and are, on the whole, superior to air-drains.

Horizontal Damp-Proof Course.—Even where air-drains are provided, a damp-proof course should be inserted in all walls, to prevent the moisture out of the soil from rising in the masonry.

The damp-proof course should be 6 inches or more above the level of the external ground, but under the wall-plate carrying the floor-joists.

There are several forms in which a damp-proof course may be provided.

It may be of glazed pottery slabs built into the wall, as shown at D D in Fig. 154. The joints between the slabs must be left empty, or the damp will rise through them.[1]

A layer of tough asphalte about $\frac{3}{8}$ inch thick is often used instead, as at A in Fig. 155.

In buildings finished with a parapet wall, a damp-proof course should be inserted just above the flashing of the gutter, so as to prevent the wet which falls upon the top of the parapet from soaking down into the woodwork of the roof and into the walls below.

In some localities damp-proof courses are formed of asphalted felt, or with slates set in cement; these latter are rather liable to crack, and thin impervious stones, or courses of Staffordshire bricks in cement, are better. Sheet lead has been used for the same purpose, and is most efficacious, but very expensive.

Arches over vaults, or cellars under footpaths, are frequently rendered all over the extrados with asphalte or cement to prevent the penetration of wet.

Vertical Damp-Proof Course.—In addition to the precautions adopted to prevent damp out of the ground from rising in walls, it is necessary (especially when using inferior bricks or porous stones) to prevent moisture falling upon the outer face from penetrating to the interior of the wall.

The wet may be kept out of the interior of the wall by rendering the exterior surface with cement, covering it with slates fixed on battens, or with

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[1] To prevent wet which comes into the hollow space, through the outer portion of the wall, from finding its way along the top of the damp-proof course to the interior of the wall, a cement fillet may be run along the angle at the bottom of the hollow space between the top of the damp-proof course and the inner portion of the wall, and an exit should be afforded—in any case temporarily—for the water at various points by leaving openings in the brickwork. If these openings are left permanently they should be protected by gratings.

glazed tiles set in cement. Taylor's pottery facing bricks answer the same purpose.

Another plan patented by Mr. Taylor consists of overlapping slates placed vertically in the middle of the wall—the two portions of which are united by peculiar iron ties.

The Hygeian rock impervious wall-lining, patented by Mr. White of Abergavenny, consists of a vertical sheet of waterproof composition introduced into the thickness of the wall.

The wall is built up, two or three courses at a time, in two vertical slices, with about ½-inch opening between them, the inner parts of the horizontal joints next to this opening being left empty. The melted composition being run in, fills all the openings thus left, and not only prevents the penetration of moisture but adds to the strength of the wall.

It is stated that a 9-inch wall built with the lining is stronger than an 18-inch wall built in the ordinary way.

Fig. 152 from Mr. White's circular, shows the application of his system to a water-tight tank.

This system may often be useful for parts of buildings in very damp places, but it must be remembered that walls perfectly impervious to air are, for sanitary reasons, undesirable for inhabited rooms.

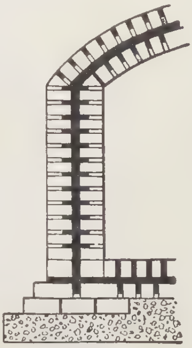


Fig. 152.

Hollow Walls not only exclude the damp, but the layer of air they contain being a non-conductor of heat tends to keep the building warm. Such walls are formed in two separate portions, standing vertically parallel to one another, and divided by a space of about 2 or 3 inches, sometimes 4½ inches.

These two portions are generally united either by special bonding bricks or by iron cramps. There are several ways of arranging the thickness of the portions of the wall, and the consequent position of the air space.

In some cases the two portions are of equal thickness, the air space being in the centre.

Very frequently one of the portions is only 4½ inches thick, built in brickwork in stretching bond; the other is of such thickness as may be necessary to give the whole stability.

In such a case the thin 4½ portion is sometimes placed on the outer, and sometimes on the inner side of the wall.

Hollow Walls with the thin portion inside.—In some cases, such for instance as when the wall has a stone face, the 4½-inch portion is necessarily on the inside, but this arrangement has many disadvantages.

In the first place, the bulk of the wall is still exposed to damp, and the moisture soaks in to within 7 or 8 inches of the interior of the building.

Again, if the wall has to carry a roof, expense is caused, as the span should be increased so as to bring the wall-plates on to the outer or substantial part of the wall, clear of the $4\frac{1}{2}$-inch lining.

This may be avoided by bridging over the air-space, so as to make the wall solid at the top, which, however, renders it liable to damp in that part.

There is an advantage in having the thick portion of the wall outside when deep reveals have to be formed for the door and window openings.

Hollow Wall with the thin portion outside.—If the $4\frac{1}{2}$-inch portion is placed outside, the damp is at once intercepted by the air-space, kept out of the greater portion of the wall, and at a considerable distance from the interior of the building.

The roof can be economically arranged so as to rest upon the interior thicker portion of the wall.

The stretching bond is, however, considered by some to be unsightly, unless made to appear like English or Flemish bond by using false headers, and, where the bricks are bad, the thin exterior portion, if liable to be attacked by frost, is in time destroyed.

Moreover, when the thin portion is outside, there is some difficulty in constructing deep reveals in a solid manner without their becoming a channel for damp across the opening. On the whole, however, the arrangement with the thin portion outside is the best.

Hollow Walls with Bonding Bricks.—Jenning's patent bonding bricks are made of vitrified pottery, and are of the shape shown in Fig. 153. These bricks are built in across the opening at

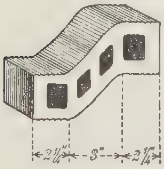


Fig. 153.

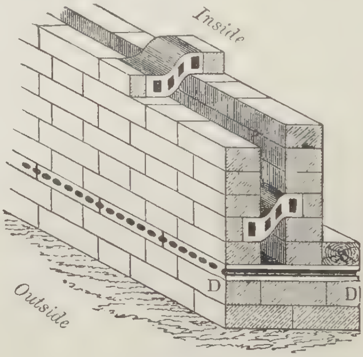


Fig. 154.
Scale, $\frac{1}{2}$ inch = 1 foot.

horizontal intervals of about 2 feet 6 inches and vertical intervals of about 9 inches to 12 inches. The bricks in the several courses are placed chequer-wise, so that each is over the interval between two below.

The peculiar shape of the brick enables it to be built into the wall so that the end in the front portion is a course lower than the end in the back portion of the wall. This prevents any

moisture running along the surface of the bonding brick to the interior of the wall.

Precautions.—When building with these bricks, it is advisable to cover them temporarily with a pipe swathed in hay bands, or by a narrow strip of wood, in order to prevent the falling mortar from lodging upon them. As the wall rises, the strip is transferred in succession from each row of bonding bricks to cover the last built in.

Sizes.—The bent bonding bricks shown in Figs. 153-154 are made in four sizes from $7\frac{1}{2}$ inches to $13\frac{1}{2}$ inches horizontal length between their ends.

Their lengths and shape are arranged so as to afford either a 3-inch or a $4\frac{1}{2}$-inch cavity, and to enter the wall either $2\frac{1}{4}$ inches at both ends—$2\frac{1}{4}$ at one end and $4\frac{1}{2}$ inches at the other—or $4\frac{1}{2}$ inches at both ends.

The bonding bricks may extend right through the thin portion of the wall, or, if this is objectionable on account of appearance, their ends may be covered by bats, as shown in the figure.

Hollow Walls with Iron Ties and Cramps.—Ties of cast iron, Fig. 156, or of wrought iron, Fig. 158, and *x* and *y* Fig. 155 dipped when hot in tar, are frequently used instead of bonding bricks, and have the advantage of not being liable to be broken if the wall should settle unequally. On the other hand, they are subject to decay by rust, and to expansion from the same cause, which may injure the wall.

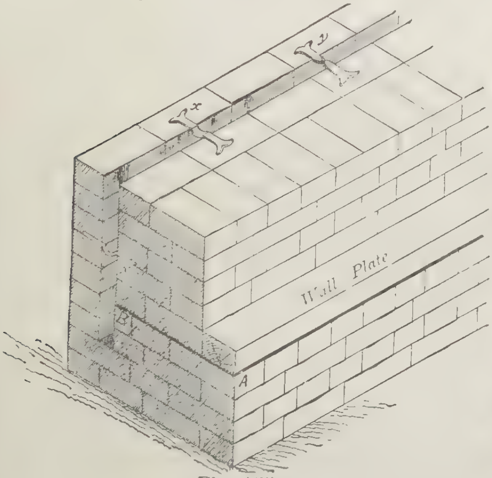


Fig. 155.
Scale, $\frac{1}{2}$ inch = 1 foot.

Fig. 156.

Fig. 157.

Fig. 158.

Fig. 159.

The ties are about 8 inches long, $\frac{3}{4}$ inch wide, by $\frac{1}{10}$ inch thick; they are placed about 3 feet apart, horizontally, and with 9-inch vertical intervals between the rows.

Each tie is either bent or twisted in the middle, so as to stop

[1] Figs. 156-159 are from Messrs. Chambers, Monnery, and Co.'s advertisements.

the passage of water along its surface, and hollow iron ties possessing great strength as struts have for some time been introduced.

Cast-iron cramps are made about $\frac{1}{2}$ inch wide and $\frac{3}{16}$ thick, and somewhat similar in form to the above.

The hollow wall is often arranged to begin on the damp-proof course (see page 62), but it is better to continue the hollow for two or three courses lower, as shown in Fig. 155, so that any wet falling into the cavity may be well below the damp course. When this is done the asphalte course may be continued only across the inner thickness (AB, Fig. 155) of the wall. A covering course of brickwork is placed on the top of the air-space, which should have no communication with the outer air.

Some walls are built entirely of hollow bricks made for the purpose.

Stone walls are sometimes lined with $4\frac{1}{2}$-inch brickwork on the inside, an air flue about 2 inches wide being left between the masonry and the brickwork.

Hollow Walls built with common Bricks only.—In the absence of iron cramps or bonding bricks, hollow walls may be built with ordinary bricks placed on edge, after being dipped in boiling tar to make them as non-absorbent as possible. Every course is composed of alternate headers and stretchers, so arranged that each header comes immediately over the centre of a stretcher in the course below. The wall thus formed consists of two portions, each 3 inches thick, separated by a 3-inch space.

Another plan is to lay the bricks as in ordinary English bond, leaving a space of about $2\frac{1}{2}$ inches between the stretchers in the front and back. This makes the wall $(4\frac{1}{2} + 2\frac{1}{2} + 4\frac{1}{2}) = 11\frac{1}{2}$ inches thick, and the headers are therefore too short to reach from face to back; the deficiency is made up by inserting bats at the ends of the headers.

These and other plans adopted for building hollow walls with ordinary bricks are defective in strength as compared with the walls constructed with special bonds or cramps, and, moreover, the common bricks being porous, conduct moisture to the interior of the wall and defeat the object aimed at in making it hollow.

A better plan, in the absence of the special bonding bricks or ties, is to unite the portions of the wall by pieces of slate slab, or of dense impervious stone, used in the same way as the iron ties.

Openings in Hollow Walls.—Where the lintels of doors and windows occur in a hollow wall with a $4\frac{1}{2}$-inch exterior portion, the following arrangement may be adopted to prevent the wet which may enter the air-space from dropping upon the window or door frame.

Just above the window or door head a piece of sheet lead is built in on the inner side of the $4\frac{1}{2}$-inch exterior wall. This lead may be $4\frac{3}{4}$ inches wide, 2 inches being built into the $4\frac{1}{2}$-inch wall, $1\frac{3}{4}$ inch projecting into the air-space, and the remaining inch turned up so as to form a sort of gutter, which should be carried about 2 inches farther than the ends of the lintel each way, so as to lead the water clear of the door or window frame.

JOINTS.[1]

Mortar is used to cement the parts of a wall together, and also to prevent the fracture of the bricks or stones by insuring an even distribution of pressure, notwithstanding any irregularities in their beds.

The quantity and coarseness of the mortar that should be used will therefore decrease in proportion as the beds are more perfect; *e.g.* ashlar masonry has thinner joints than rubble, and good bricks can be set with closer joints than bad ones.

Thickness of Joints.—Excessively thick joints should be avoided when possible. They not only injure the appearance of the work, but, when the weight of the superincumbent walling comes upon them, the mortar is squeezed out, projects beyond the face of the wall, catches the rain, and leads it into the wall, rendering the work liable to injury by frost.

In good brickwork (not gauged) the joints should be about $\frac{1}{4}$ to $\frac{3}{8}$ inch thick. For ashlar masonry or gauged brickwork about $\frac{1}{8}$ to $\frac{1}{10}$ inch thick, while for rubble they vary in thickness according to the nature of the work.

The bricks or stones should be wetted so as to remove the dust, which would prevent the mortar from adhering to them, and also to prevent them from sucking the water out of the mortar. The mortar should be used stiff, and every joint well flushed, all interstices being filled with bits of brick or stone set in mortar.

Larrying is the method usually adopted for filling in the interior of very thick walls. After the bricks forming the exterior faces of a course are laid, a thick bed of soft mortar is spread between them, and the bricks for the inside of the wall are one by one pushed along in this bed until the mortar rises in the joints between them.

Grouting consists in pouring very liquid mortar over the course last laid, in order that it may run into all vacuities left by careless workmanship in not properly filling up all the internal joints with mortar. Grout is, however, a weak and objectionable form of mortar.

The joints, both of brick and of masonry, are finished so as to present a neat appearance on the face in several different ways, as in Pl. I., in which the joints are shown full size.

Flat or Flush Joints.—In these the mortar is pressed flat with the trowel, and the surface of the joint is flush with the face of the wall, as at *a* Pl. I.

Such joints are not very ornamental, but are suitable for internal surfaces to be whitewashed.

Flat Joints jointed, *b* Pl. I., are the same as those last described, except that an iron jointer is used to mark a narrow line along the centre of the joints, which improves their appearance. Sometimes both the upper and the lower edges of the joint are jointed as in *c* Pl. I.

[1] Joints in Stonework are described in Chap. III.

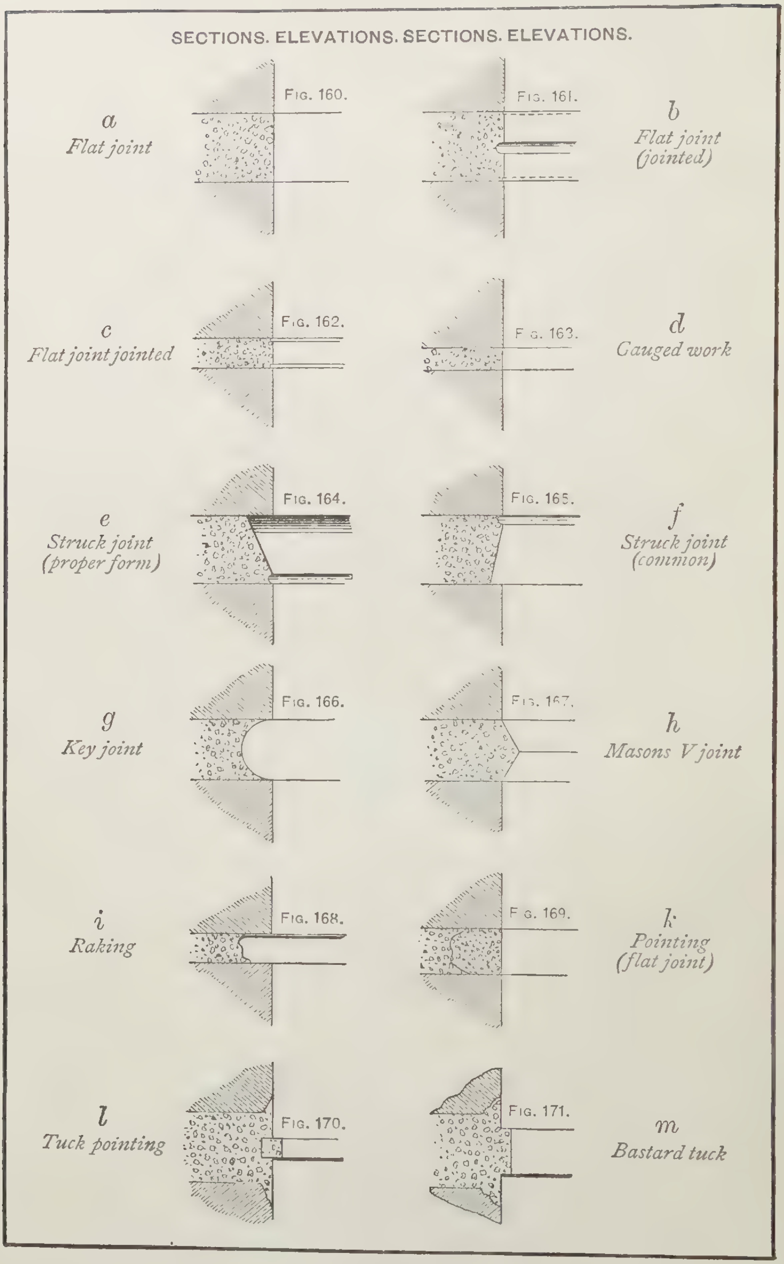

SECTIONS. ELEVATIONS. SECTIONS. ELEVATIONS.
Fig. 160.
a
Flat joint
Fig. 161.
b
Flat joint (jointed)
Fig. 162.
c
Flat joint jointed
Fig. 163.
d
Gauged work
Fig. 164.
e
Struck joint (proper form)
Fig. 165.
f
Struck joint (common)
Fig. 166.
g
Key joint
Fig. 167.
h
Masons V joint
Fig. 168.
i
Raking
Fig. 169.
k
Pointing (flat joint)
Fig. 170.
l
Tuck pointing
Fig. 171.
m
Bastard tuck

Plate I.

Gauged work (see page 29) has very thin joints (see *d* Pl. I.) formed by dipping the bricks in white lime-putty before laying them.

Struck Joints should be formed by pressing or "striking" back the upper portion of the joint while the mortar is moist, so as to form a sloping surface which throws off the wet (see *e* Pl. I.); the lower side of the joint is cut off with the trowel to a straight edge.[1] These joints are usually struck along the *lower* edge as at *f* Pl. I.; a ledge is thus formed above which catches the rain.

Keyed Joints, *g* Pl. I., are formed by drawing a curved iron key or jointer along the centre of the flush joint, pressing it hard, so that the mortar is driven in beyond the face of the wall; a groove of curved section is thus formed, having its surface hardened by the pressure.

In some cases the moist key is dipped into ashes, which are thus rubbed into the surface of the joints.

Mason's or V Joints, *h* Pl. I., project from the face of the wall with an angular V section. With good mortar they throw off the wet, but when inferior lime is used they soon become saturated and destroyed by frost.

Raking and Pointing consists in removing the original mortar joints to a depth of about $\frac{3}{4}$ inch in from the face, *i* Pl. I., filling in with mortar, *k* Pl. I., and finishing the joints in one of the methods about to be described.

Pointing is not advisable for new work, when it can be avoided, as the joints thus formed are not so enduring as those which are finished at the time the masonry is built.

During severe frost, however, it would be useless to strike the joints at the time the work is built, for the mortar would be destroyed by the frost.

Pointing is, moreover, often resorted to when it is intended to give the work a superior appearance, and also to conceal the defects of inferior work.

In repairing old masonry or brickwork, the mortar of which has become decayed, raking out and pointing become necessary.

Both in old and new work, before pointing, the original mortar should be raked out with an iron hooked point, and the surface well wetted before the fresh mortar is applied.

Flat Joint Pointing.—The raked joints are filled in with fine mortar, and struck flat with the trowel or jointer, as at *k* Pl. I. They may be jointed as at *b* Pl. I.

Tuck Pointing, *l* Pl. I., is used chiefly for brickwork; the joints having been raked are "stopped," that is, filled up flush with mortar. This is coloured or rubbed over with a soft brick

[1] Joints so struck are sometimes called *weather joints.*

until the joints and bricks are of the same colour. A narrow groove is then cut along the centre of each joint, and the mortar is allowed to set. After this the groove is filled with pure white lime-putty, which is caused to project so as to form a narrow white ridge, the edges of which are cut off parallel so as to leave a raised white line about $\frac{1}{8}$ inch wide. This process causes inferior work to look as if it had been executed with large bricks and very fine joints; in carrying it out any defects in the work, such as irregularity of joints, are corrected by smearing over the face and striking false joints, so that badly executed work is disguised and made to present a good appearance.

Bastard Tuck Pointing, *m* Pl. I., consists in forming a ridge from $\frac{1}{4}$ to $\frac{3}{8}$ wide on the stopping itself, the edges being cut parallel and clean. There is no white line, the projecting part of the joint being of the same colour as the remainder.

Blue or Black Pointing is done with mortar mixed with ashes instead of sand.

Keying for Plaster.—When a wall is to be plastered, the joints are either raked as at *i* Pl. I. or the mortar joints are left rough and projecting—in either case to form a key for the plaster.

Vertical joints are similar to horizontal joints, but in many cases are much thinner.

VARIOUS BONDS NOT MENTIONED IN CHAP. II.

The principal bonds used in brickwork were described in Chap. II., but there are one or two varieties not so commonly used which remain to be noticed.

Raking Bond is of two kinds, *Diagonal* and *Herring-bone.* In both the bricks in the interior of the wall are placed in directions oblique to the face. A course or two of raking bond is sometimes introduced at intervals in thick walls built in English bond.

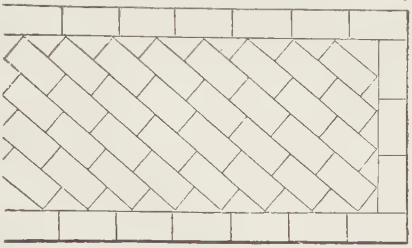
The proportion of stretchers in a brick wall diminishes according to its thickness (see Chap. II.) The raking courses are therefore useful in giving longitudinal strength to thick walls which are deficient in stretchers.

In both kinds of raking bond alternate courses rake in opposite directions.

Diagonal Bond.—In this the bricks (except those in the faces of the wall) are laid diagonally, at such an angle with the face that the bricks will just fit in without being cut.

A two-brick wall is the thinnest in which this can be done, and then only in the stretching courses. In thicker walls diagonal bond may be inserted in any course.

The triangular spaces at the back of the facing bricks are objectionable; it takes some trouble to cut a piece to fit them, and they are therefore frequently left empty.



DIAGONAL BOND.
Fig. 172.

HERRING-BONE BOND consists of bricks laid raking from the sides toward the centre line of the wall, as shown in Fig. 173.

This is a defective bond, for, in addition to the triangular spaces at the back of the facing bricks, there are likely to be voids, each larger than half a brick, left in the centre of the wall, unless great care be taken to have them properly filled in.

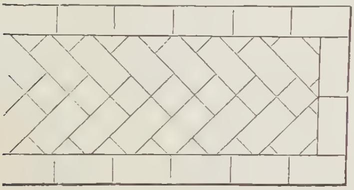


Fig. 173.

Herring-bone courses cannot be introduced at all in walls less than 3 bricks thick, and only in the stretching courses of such a wall; in thicker walls, however, this bond may be introduced in any course.

In practice this bond is rarely, if ever, adopted for walls.

Garden Bond is of two kinds—

ENGLISH GARDEN BOND consists of one course of headers to three or four courses of stretchers.[1]

FLEMISH GARDEN BOND contains in each course one header to three or four stretchers.

The object in each case is the same, to show as few headers as possible, in order to get a fair face on both sides of walls 9 inches thick, for which such bond is chiefly used.

This would not be possible if there were many headers, because ordinary bricks vary so much in length.

Bond Courses of superior construction are sometimes built into inferior walls to strengthen them.

Thus courses of brickwork may be built into walls of flints or rubble, and are called *lacing courses*.

[1] Known also as *Scotch Bond* and in some localities as *Common Bond*.—SEDDON.

Brick Piers are generally rectangular, and may be built either with or without reveals.

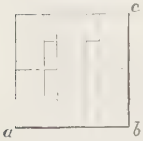


Fig. 174.

Fig. 174 is a plan of one course of a pier 18 inches square, without reveals, built in English bond.

The next course is precisely similar as regards bond, but is placed at right angles to the first, being turned round so that the side *a b* in the course coincides with *b c* in Fig. 174. The same remark applies to Figs. 175 and 176.

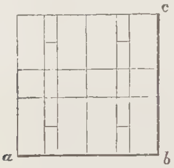


Fig. 175.

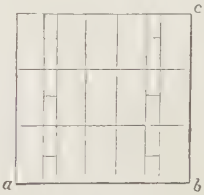


Fig. 176.

Fig. 175 is the plan of a pier $2\frac{1}{2}$ bricks square, and Fig. 176, of one 3 bricks square, both in English bond.

It will be noticed from these figures that in piers whose sides are equal in length to an even number of half-bricks (Figs. 174-176) all the bricks of the stretching courses are whole bricks, but when the sides are of a length equal to an uneven number of half-bricks (Fig. 175) a line of half-bricks or of headers must be introduced in each stretching course.

Bond of Walls forming Obtuse and Acute Angles.—The

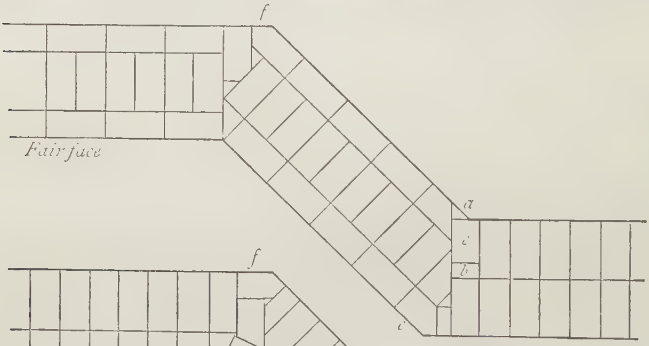


Fig. 177.

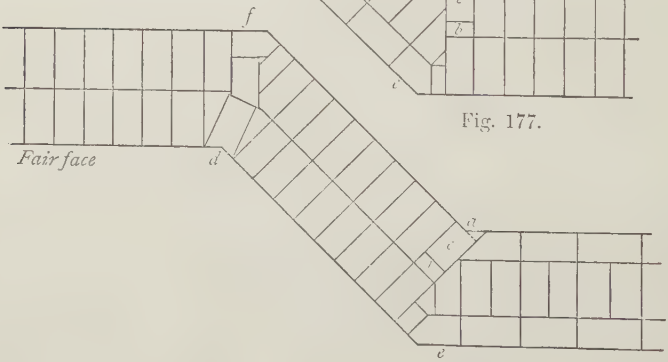


Fig. 178.

methods of arranging the bond for walls meeting at a right angle, as is most commonly the case in buildings, have been explained in Chap. II.; an illustration will now be given of the bond for walls meeting at an inclination greater or less than a right angle.

OBTUSE ANGLES.—Figs. 177 and 178 show two 18-inch brick walls meeting at an obtuse angle.

There are several ways of forming the bond, but the arrangement shown is a good one.

The bird's-mouths *a* and *d* and the squints *e e*, Figs. 177, 178, may be "cut and rubbed" as "axed fair," or specially moulded. The squints *f f* would be "rough cut."

To avoid cutting the bird's-mouth in the brick at the re-entering angle, the little triangular points *a* are often very improperly put in as separate pieces, in which case the bat *b* is not required, *b* and *c* being replaced by a whole brick.

ACUTE ANGLES.—In Figs. 179 and 180 two 18-inch brick walls meet at an acute angle.

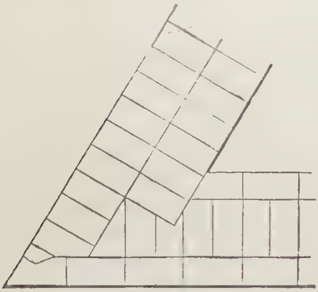


Fig. 179.

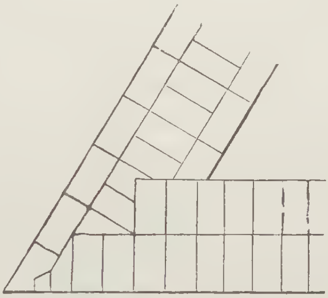


Fig. 180.

The bonds shown involve a good deal of cutting, which is inevitable to form really good work, but much of it would be omitted in ordinary building, the resulting gaps and spaces being filled in with bits of brick bedded in mortar.

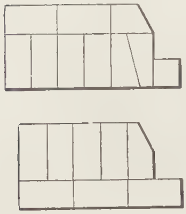
Reveals with Splayed Jambs.[1]— Splayed jambs in brickwork are weaker than square jambs, and should only be used where there is a good interval between the windows.

Figs. 181, 182, are plans of the alternate courses of a reveal with splayed jambs for a 14-inch ($1\frac{1}{2}$-brick) wall in English bond. Figs. 183, 184, are plans of the same in an 18-inch (2-brick) wall.

[1] Reveals with square jambs are described in Chapter II.

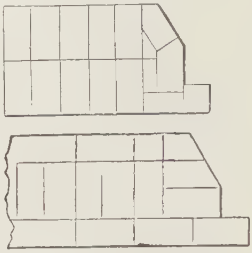
ENGLISH BOND.

1½-Brick Wall.



Figs. 181, 182.

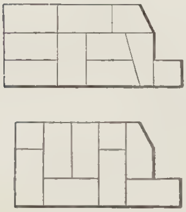
2-Brick Wall.



Figs. 183, 184.

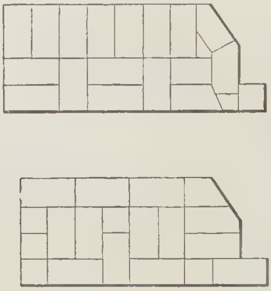
FLEMISH BOND.

1½-Brick Wall.



Figs. 185, 186.

2-Brick Wall.



Figs. 187, 188.

Figs. 185-188 give the same information for 14-inch and 18-inch walls in Flemish bond. There is a peculiarity in the bond of these walls which was noticed but not illustrated in Chap. II. It will be seen that there are no false headers in the face. Every header is a whole brick: this makes stronger work, and causes fewer splits in the wall than the ordinary single Flemish bond illustrated in Chap. II.

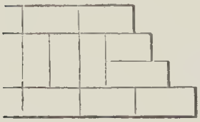


Fig. 189.

When splayed jambs are to have linings, they may be built with square offsets, as in Figs. 189, 190.

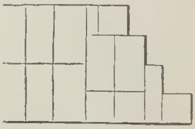


Fig. 190.

Arches.—It has been stated in Chap. II. that small rough arches of brickwork are generally turned in half-brick rings, and that this is especially necessary when the arch is of a quick curve, in order to avoid large joints upon the extrados.

Some authorities, however, recommend that flatter arches, especially those of larger span, should be built in 9-inch rings. This may be done in two or three different ways.

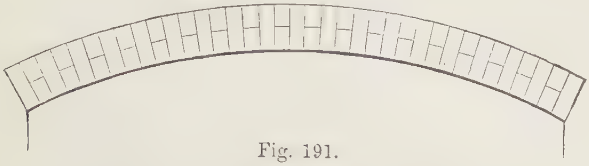


Fig. 191.

1. In English Bond.—Fig. 191 being the section, and the plan consisting of alternate courses of headers and stretchers, presenting the appearance of English bond on the soffit of the arch.

2. In Flemish Bond.—The section being like that in Fig. 191, and the soffit showing the same arrangment as the face of a wall built in Flemish bond.

3. In Heading Bond.—The ring throughout consisting of headers as in the section, Fig. 192, excepting at the ends of the arch, where three-quarter bricks are introduced to break the bond, in the same manner as is done in the face of a wall built in heading bond.

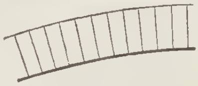


Fig. 192.

Of the above varieties the heading bond is the strongest, as the voussoirs are each in one piece and no bats are required; but it is very difficult to make neat work with such a bond, and it is therefore very seldom adopted.

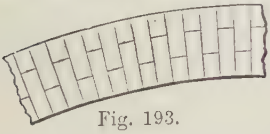


Fig. 193.

Arches $1\frac{1}{2}$ Brick thick may be built as shown in Fig. 193, which represents a section; the end elevation of the arch is the same, and the plan is like the face of a wall in English bond.

1. Arches Turned in Whole-brick Rings consist of rings like that in Fig. 192 superposed one over the other.

2. Arches in Half-brick Rings (see Fig. 194) are very commonly used, and are easily built; they should not, however, be adopted for spans exceeding 30 feet. The rings have a tendency to settle unequally; in such a case the whole weight may be thrown for a moment upon a single ring; if this is crushed, the pressure comes upon the next ring, and so on, resulting in the failure of the whole arch.

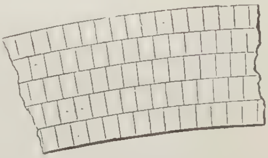


Fig. 194.

In building arches with half-brick rings it is advisable to build the undermost ring with thin joints and gradually to thicken the mortar joints as the extrados is approached; this prevents the lowest ring from settling while those above remain in position, which would cause an ugly fissure.

Arches with Bond Blocks.—To avoid the disadvantages above mentioned, arches have been built with blocks, B B, set in cement, running through their thickness at intervals, so as to form a bond right through the thickness of the arch.[1] Stone bonds may be used instead, cut to the shape of a voussoir. These bond blocks should be placed at the points where the joints of the various rings coincide: those points will be determined by the radius of curvature of the arch, the thickness of the bricks, and of the joints.

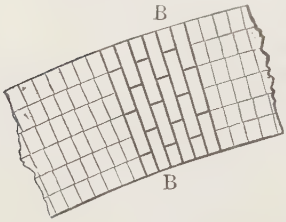


Fig. 195.

Bonding Rings in Pairs.—Another arrangement consists in introducing headers so as to unite two half-brick rings wherever the joints of two such rings happen to coincide. The rings are sometimes thus united in consecutive pairs right through the thickness of the arch.

Thick Arches bonded throughout their Depth, as shown in Fig. 196, have sometimes been used for large spans.

The joints in the extrados are necessarily very wide, but the evil effects of this may be guarded against by using cement or quick-setting mortar, or by wedging up the joints of the outer portion with pieces of slate. In this latter case, however, the inner rings are apt to be relieved of pressure, and the stretchers are liable to drop out.

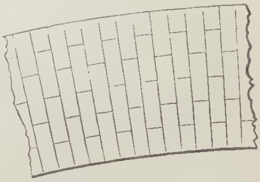


Fig. 196.

Arches of large Span, in whatever way they are bonded, should be built in good hydraulic mortar, setting moderately quickly, so that when the centres are struck the joints may be soft enough to adapt themselves to the inequalities of the bricks, and thus enable them to obtain a firm bearing. Hoop-iron bond is sometimes introduced between the rings parallel to the soffit.

In ordinary buildings, however, arches of large span are seldom required, and they need not, therefore, be further alluded to.

[1] The block B is drawn in thicker lines to make it distinct, but its joints are of the same thickness as those of the rest of the arch.

Bond Timbers were at one time extensively used to give longitudinal strength to walls, but they are injurious in many ways. In process of time they shrink, they rot, and, in case of fire, they burn away; in either instance the whole superincumbent weight of the wall is thrown upon a small portion of it, or again, they may absorb moisture, swell, and overthrow the masonry.

Ranging Bond consists of narrow horizontal pieces built into the joints of walling parallel to one another at intervals of about 18 inches, to form grounds for battening, etc. etc. The face of the pieces projects slightly from the wall, so that the battens may be clear of the masonry.

Dry wood plugs[1] may be used instead, let into holes cut in the stones or bricks, not in the beds or joints, otherwise they may swell and disturb the wall.

It has already been stated that timber in every shape and form should be kept out of brickwork and masonry as much as possible; where it is absolutely necessary to insert it in order to form a hold for woodwork, etc., the pieces should be as small as practicable.

Hoop-iron Bond, consisting of strips of hoop-iron (about $1\frac{1}{2}$ inch broad and $\frac{1}{16}$ to $\frac{1}{20}$ inch thick), tarred and sanded, and inserted in the joints as shown in Fig. 197, is far preferable to bond timbers, and is frequently used, especially in half-brick walls.[2]

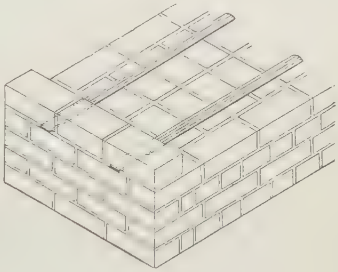


Fig. 197.

The hoop-iron should in every case be thoroughly protected from the action of the atmosphere, or it will oxidise and destroy the masonry; if used in thin walls, they should always be built in cement.

The ends of the hoop-iron should be bent so as to hook one another at the joints in the length, and at corners where two walls meet, forming an angle.

Pieces of hoop-iron are often used to make a junction where the bond of the brickwork is defective (see Chap. II.)

BRICK DRAINS AND SEWERS.

Brickwork is evidently not adapted for drains of very small

[1] Breeze-bricks (see Chap. II.) may be substituted for these.

[2] Sometimes one or two strips are used for each brick in the thickness of the wall. —Seddon, *Builders' Work.*

diameter, as there are, necessarily, very wide joints on the extrados of rings turned to a quick curve.

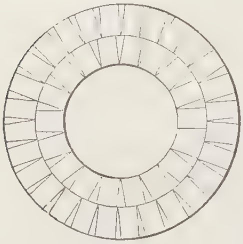


Fig. 198.

Earthenware pipes, being cheaper and preferable in every way, have in most cases long since superseded brickwork for drains of less than 18 inches or 2 feet in diameter.

Circular Drains.—When pipes are not procurable, circular drains may be constructed with bricks as shown in section Fig. 198.

This figure shows an 18-inch drain constructed with two half-brick rings, but as a rule the thickness of the brickwork need not be more than one ring, (or $4\frac{1}{2}$ inches) in sewers of less than 3 feet diameter.

Covered Drain.—Another form of brick drain consists of a semicircular inverted arch covered with a flat stone, S, the removal of which gives easy access to the drain for examination.

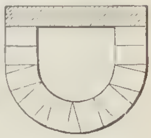


Fig. 199.

Egg-shaped Sewers may be constructed of the section shown in Fig. 200. The proportions of such sewers vary according to circumstances; but in all cases the invert, *i*, should have a quick curve (of radius not exceeding 9 inches), and the crown should be a semicircle.

The usual method of construction is to make the diameter of the invert half that of the crown, and the height of the sewer equal to 3 times the diameter of the invert.

Thus in Fig. 200—

$$hi = cf = 1. \quad gh = \tfrac{1}{2}. \quad ai = df = dk = 3.$$

The invert may be formed either of brickwork in cement, with a terra-cotta invert block, or with an invert block bedded in concrete, as shown at B in Fig. 200.

Comparative Advantages of Oval and Circular Forms.—Oval or egg-shaped sewers are the best adapted for situations where there is an intermittent flow of sewage—that is, when the quantity passing varies considerably at different times.

The reason for this is, that at the time when there is but a small quantity of sewage passing, it occupies in the narrow bottom of the egg-shaped sewer a greater depth than it would in a circular sewer of the same area of section.

This increased depth of the sewage causes it to flow with greater velocity, and thus renders the sewer more efficient.

When the flow of sewage is nearly uniform the circular sewer may be adopted, and will be found stronger and cheaper than the other.

Bricks for sewers should be of the hardest possible description, and laid

in hydraulic mortar. Even the best bricks will be gradually destroyed by the sewage.

The inverts especially require to be of hard lasting material with a smooth surface, so as to resist as little as possible the passage of the sewage matter passing over them. They should, therefore, be formed with a smooth terra-cotta or fireclay invert block, as shown in Fig. 200, or built with glazed or very smooth bricks. Bricks "purpose-moulded" to the radii make the best sewers; but where they cannot be obtained, blocks are sometimes formed with common bricks placed in frames, grouted and formed into a solid mass with cement.

When sewers are constructed in a porous soil, the invert should be very carefully built, and a lining of puddle clay placed outside the sewer, so as to render it water-tight to half its vertical depth.

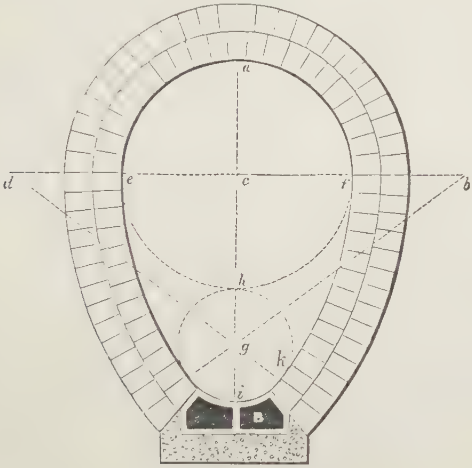


Fig. 200.

Great care should be taken in filling in over sewers, so that large clods or masses of earth may not be allowed to fall upon the brickwork and injure it.

Sewers are frequently built in concrete either alone or combined with brickwork.

When concrete is used by itself it is sometimes rammed into a trench round a mould of the section intended for the sewer, so that the sewer consists of a rectangular block of concrete containing a circular or egg-shaped tunnel.

In many cases, however, the concrete is lined with brickwork, and sometimes the lower part only of an egg-shaped sewer is built in brickwork, the upper portion being finished with concrete rammed in over a centre.

Concrete is also much used for the foundations of sewers in unfavourable positions; the lower half of the sewer is imbedded in a block of concrete, which is made of a width and thickness suitable to the nature of the ground.

Sewers are also built up of hollow terra-cotta segment blocks, which fit into one another with groove and tongue joints.

The construction of drains will not be further noticed, as the

subject will be found further treated in Part II. under the heading of Plumbing and Sanitation.

CHIMNEYS.

The fireplaces in a house frequently stand one immediately over the other, and each chimney flue[1] from the lower rooms has in consequence to be carried to one side or the other to avoid the fireplaces above it.

Arrangement of Flues.—Flues from the lower stories are therefore necessarily curved, but not those from the attics; a curve is, however, considered advisable in all flues, to prevent rain or sleet from beating vertically on to the fire, and to stop down-draughts of cold air. This curve should be sufficient to prevent daylight from being seen when looking up the flue.

The funnel, or opening above the fireplace, is gathered over (see page 85), so as to be contracted to the size of flue required.

Fireplaces generally require more depth than can be provided in the thickness of the wall; this necessitates a projection to contain the fireplace and flues called the *chimney breast.* Sometimes this projection is on the back of the wall, in which case it gives more space and a more convenient shape to the room. When on the outer wall of a house it may be made an ornamental feature.

Every fireplace should have a distinct flue to itself; if the flues of two fireplaces communicate, and only one fire be lighted, it will draw air from the other fireplace, and smoke; moreover, its own smoke may enter any other room the fireplace of which is connected with the same flue.

The air heated by the fire is rarefied, rendered lighter, and ascends the flue, drawing the smoke with it, whilst cold air rushes into its place from below.

Hence the throat or lower opening of the flue should be small, so that no air may pass through it without first coming into contact with the fire and being thoroughly warmed.

The flue should not be larger than is necessary for conveying the smoke and heated air; if too large, it will smoke in certain winds.

With regard to the proper size for flues there are great differences of opinion. The size should vary according to the circumstances of different cases; but generally speaking a flue 9 inches square is sufficient to carry off the smoke from very small grates, a flue 14 inches × 9 inches for ordinary fireplaces, and a flue 14 inches × 14 inches for large kitchen ranges.

The smaller the flue, and the greater the height, the more rapid the draught and the less likely the chimney to smoke, provided that sufficient air is supplied and that the flue is large enough to carry off the smoke.

[1] Sc. *Vents.*

The flue should change its direction by gradual curves and contain no sharp angles, otherwise soot accumulates and makes it smoke. The London Building Act (1894) states that chimneys and flues having proper soot doors of not less than 40 square inches may be constructed at any angle, but in no other case shall any flue be inclined at a less angle than 45° to the horizon, and every angle shall be properly rounded (see S, Fig. 209).

Much depends upon the height of a flue, the shortest, *i.e.* those from upper rooms, or in low buildings, being most liable to smoke.

The air should pass through or very near the fire.

Thus a high opening above the fire is bad, as it admits cold air, which gets up the flue without being heated, and cools the rising warm air.

The fireplace should, therefore, be not much higher than the grate.

All walls about chimneys should be well built, and so should the "withes" or partitions between flues, as cold air may penetrate badly-built walls from the outside, or from an unused flue cold air may get into one in use, thus cooling the heated air and causing the chimney to smoke.

If openings are left in the withes, the smoke from a flue in use may penetrate another, and from it enter a room in which the fire is not burning.

Arrangement of Flues.—The width of the chimney breast for each room of a high building must be arrived at by drawing the plan of the fireplace of each room, including the flues from the fireplaces of the rooms below; they can be arranged in plan in such a form as may be most convenient for the chimney stack.

A very common practice is to build the fireplaces of adjacent rooms or houses back to back, in which case the arrangement on each side of the wall is exactly the same.

The plan of bringing a number of flues into a "stack" is economical, and tends to preserve an equal temperature in them.

First Illustration of Arrangement of Flues.—Figs. 201, 202 are respectively longitudinal and cross-sections of the fireplaces and flues in the wall between two 5-storied buildings.

The dotted lines in Fig. 202 show the direction of the flues of the fireplaces on the other side of the wall.

The remaining figures on page 83 show the plan of the chimney breasts on the level of each floor.

The weight upon the chimney breasts should be spread over a greater area by introducing footings,[1] as shown in Figs. 201, 202.

In some cases the same object is attained by turning an invert arch between the chimney breasts under the fireplace.

In order to economise the brickwork, and to leave as much

[1] Sc. *Coddings.*

interior space in the building as possible, the part of the chimney breast in each room is generally made of the minimum width that is absolutely necessary to contain the flues at that point.

Thus it will be seen that the chimney breasts on floors I K and G H are made narrower than those above them, because they contain fewer flues. The extra width required for the flues in the chimney breast on the other floors is gained by corbelling out as shown at *t t*. The projections in the brickwork are concealed under the floor and by the cornice of the ceiling below.

Sometimes one side of the chimney breast is made narrower than the other; thus the side *x* (Fig. 207) might be made narrower than *y*, and *w* narrower than *z* (Fig. 205), for in each case the chimney-breast on the left contains one flue less than that on the right. This causes an unsymmetrical appearance, but is often done even in superior buildings.

The whole of the external walls, both of chimney breasts and shafts, are generally made half a brick or only $4\frac{1}{2}$ inches thick.

It is safer, however, to make the front and outside wall of the chimney breasts 9 inches thick, especially when they are in contact with woodwork, such as skirtings, roof-timbers, etc.

Again, even when this is done, the outside wall of the chimney shaft itself is often reduced to half a brick directly it has passed through the roof. It is better, however, to keep the external walls of the shaft 9 inches thick throughout (as dotted at S S in Fig. 201), for the reasons stated at p. 88.

Second Illustration of Arrangement of Flues.—It is frequently necessary, for the sake of appearance, to place the chimney in a symmetrical position, such as the centre of the roof. To this end, and also in order to avoid a multiplicity of chimney shafts, the flues have to be collected from opposite sides of the house into a central stack.

Fig. 209 shows an example of this. The flues from the rooms A, B, C, and E, converge towards a central stack, the space between the chimney breasts of the upper rooms being bridged by an arch W, over which the flues are carried; the brickwork forming the upper wall of the flue is racked back as shown, leaving only thickness sufficient for safety above the flues.

The chimney breast of the room C cannot be carried down to the foundation, as it would interfere with the folding-doors in the room below. It is therefore supported by courses corbelled out into the room from the wall, as shown in dotted lines.

It will be noticed that the chimney breast of the room A is nearer the outer wall than that of the room below; in order to avoid widening the chimney breast below, the upper and outer chimney breast *p* is supported by courses corbelled over to one side as dotted. The corbelling is concealed by being carried out within the floor.

The projecting part of the upper chimney breast might be supported by turning an arch, as shown by the dotted line X, and this is a construction often adopted.

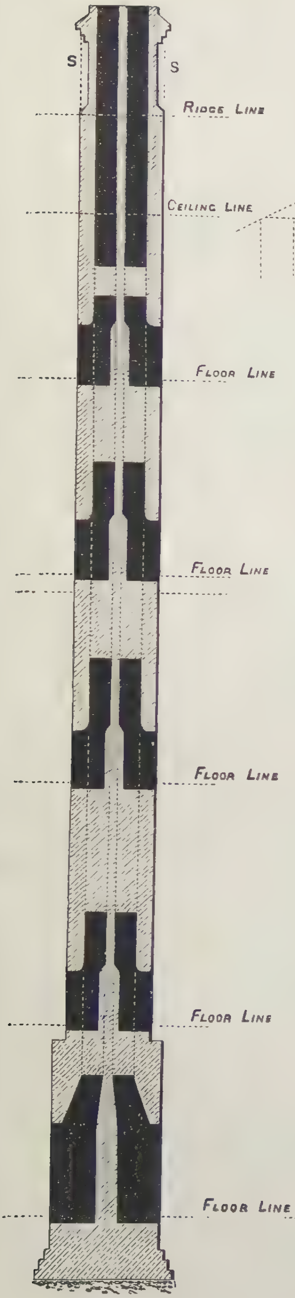


Fig. 201.

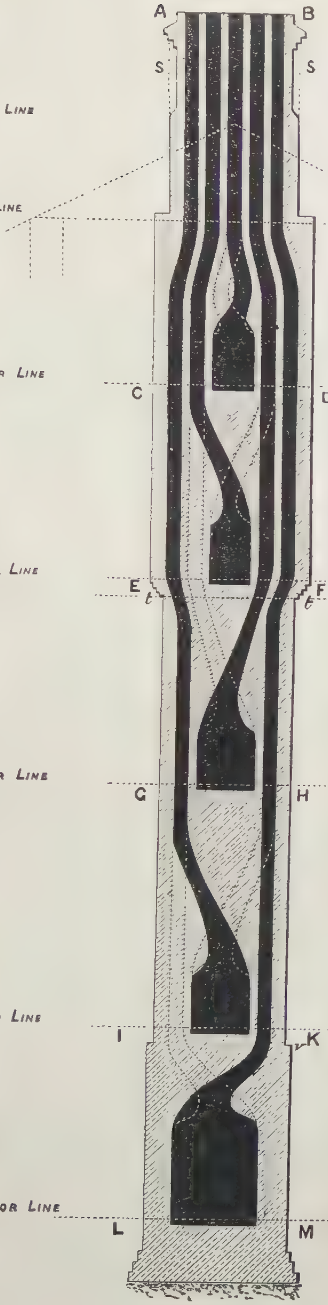


Fig. 202.

Scale, $\frac{1}{10}$ inch = 1 foot.

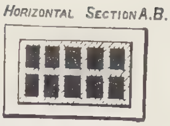


Fig. 203.

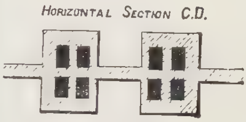


Fig. 204.

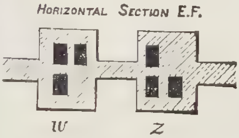
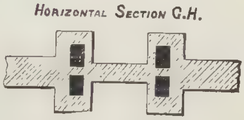


Fig. 205.



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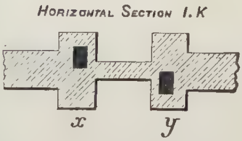

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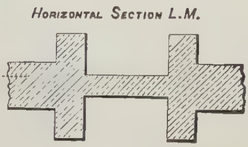


Fig. 208.

Fig. 210.

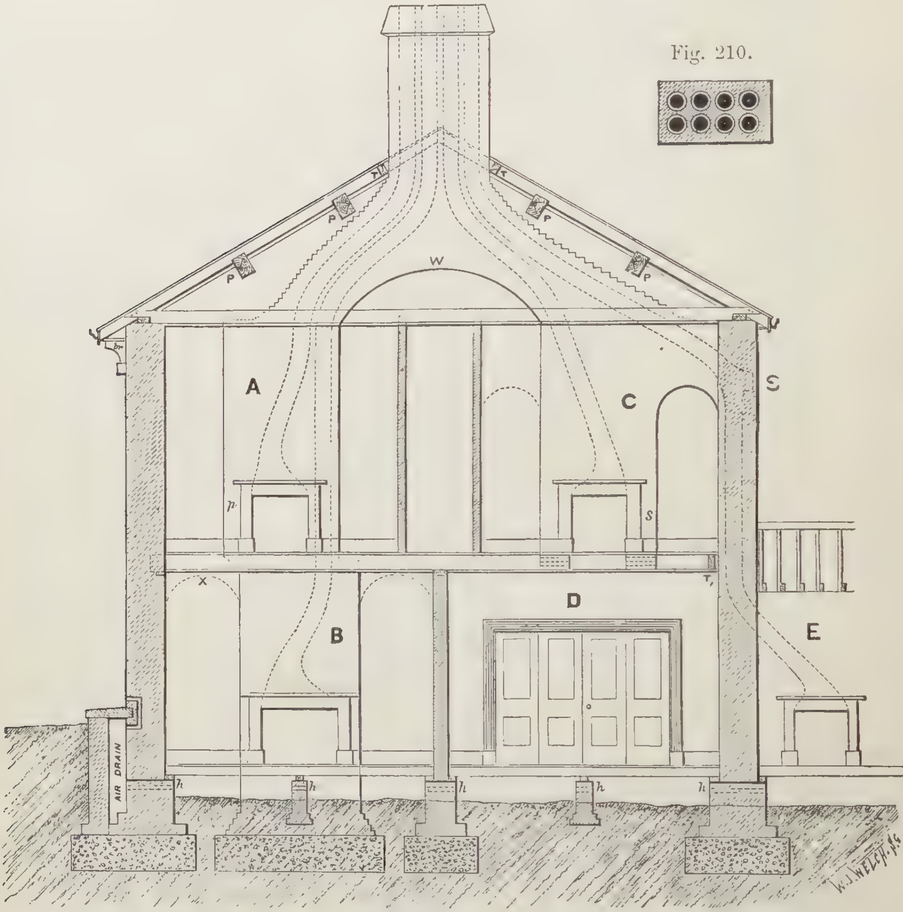


Fig. 209.

Scale, $\frac{1}{10}$ inch = 1 foot.

This Figure is the section of an ordinary dwelling-house taken on this side of the flue from E, and is intended to show two or three different arrangements of flues. It also illustrates the remarks made in Chap. X. as to the increase of roofing required when the wall plates are placed in the middle of the thickness of the walls. The whole surface of the ground may, with advantage, be covered by a layer of concrete, as described at p. 60.

It will be seen that the flue from the room E is carried vertically up in the thickness of the outer wall as high nearly as the ceiling of room C, then over an arch covering the recess between the chimney breast and the outer wall.

The portion of flue in the thickness of the outer wall is rather apt to be cold and to check the draught, and the construction might in this case be avoided by carrying the flue across the corner of the party wall of room D, and up the left chimney breast *s* (which would have to be widened to receive it) of the room C, above.

The flues in this illustration are supposed to be formed with circular earthenware pipes[1] of 9 inches diameter, shown in plan in Fig. 210.

The external walls are here shown only $4\frac{1}{2}$ inches thick, because the thickness of the flue-pipe itself affords a great protection and renders it unnecessary to make the brickwork so thick as it should be round pargetted flues.

Chimney Shafts.[2]—At the ceiling of the highest room the chimney breast is reduced in size to the chimney shaft of a width just sufficient to contain the flues. This shaft should be carried well above the roof, higher if possible than adjacent roofs or buildings, which are apt to cause eddies or down-draughts and make the chimneys smoke.

Chimney Caps.—A few of the upper courses of high chimney shafts are generally made to project, and should be built in cement to serve as a protection from the weather.

The cap is frequently made ornamental by bricks, placed anglewise, etc., in a similar manner to the brick cornices and coping referred to in Chap. II. Stone caps are also used for brick as well as for stone chimneys.

Fireplaces.—Jambs of fireplaces are built in the same manner as brick walls. The chimney breasts should be carefully founded, resting upon footings, or supported by corbels where necessary.

In order to form the throat of the chimney, the courses are "gathered" over, each projecting $1\frac{1}{8}$ inch or so over the last, until the opening is narrowed to the required dimensions. The exact projection depends of course upon the curve required. The narrowest part or throat should be immediately over the centre of the fireplace. Above the throat, the flue ascends vertically for a short distance, then gathers again to the right or left, as shown in Fig. 211.

The projecting corners of the offsets are cut off, and where the flue recedes the re-entering angles are sometimes filled up with bits of brick, or by the rendering of the flue.

[1] Sc. *Vent-linings.* [2] Sc. *Stalks.*

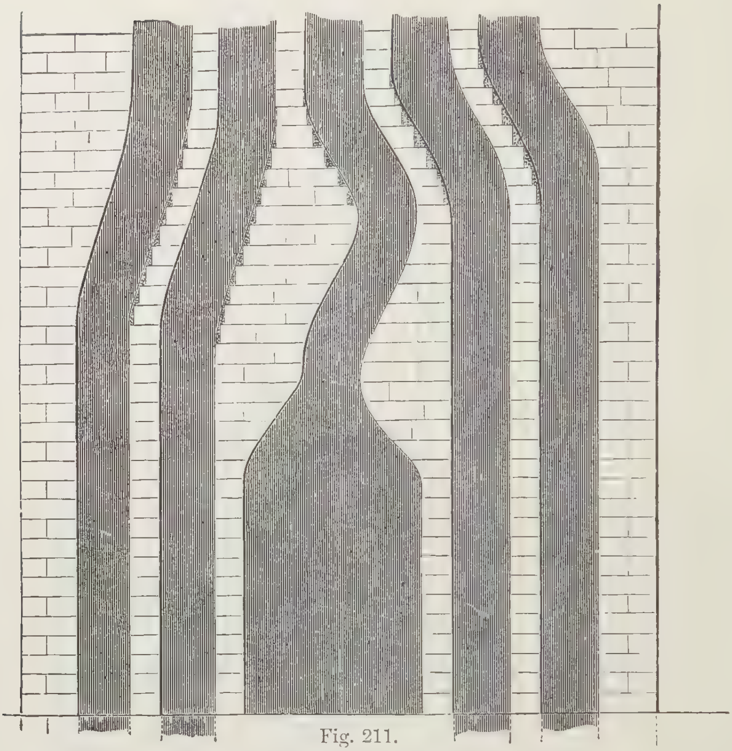


Fig. 211.

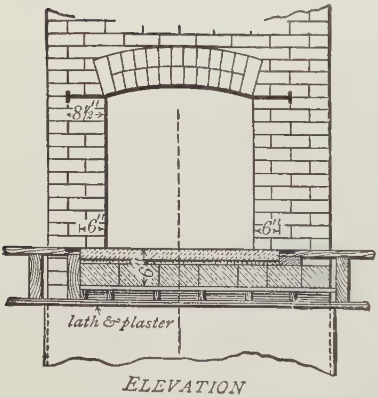


Fig. 212.

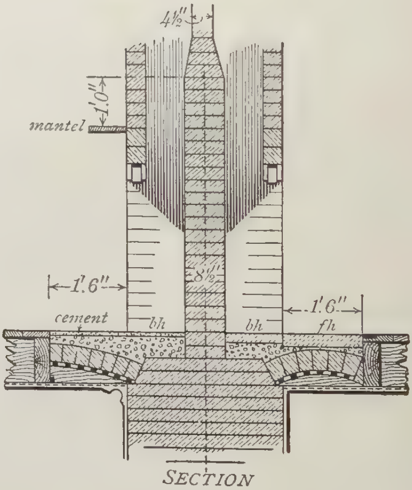


Fig. 213.

In consequence of the number of bats necessary in such work, the bond cannot be laid down beforehand, but must be left a good deal to the bricklayer.

Fig. 211 is an enlarged section of the flues contained in the chimney breast just above the floor, C D, in Fig. 202. It shows the method of gathering over for the flue of a small fireplace, and also the arrangement of the bricks in forming the withes, etc., for the flues from the stories below.

Fig. 212 is an elevation, and Fig. 213 a section, of a fireplace, showing the rough arch supported by a "*turning bar*,"[1] T T, of which a sketch is given in Fig. 214. The bricks next to the skew-backs are often laid as headers.

This bar is from $\frac{1}{2}$ to $\frac{3}{4}$ inch thick, and about 3 inches wide. It has a bearing of $4\frac{1}{2}$ inches on each jamb,[2] and beyond the bearing portions, ends about 3 inches long. These ends are sometimes split longitudinally, and *corked*,[3] *i.e.* turned in opposite directions, up and down, as shown in Fig. 214. Very frequently the ends are turned either up or down without being split, and this is a better plan than that shown, for it renders it unnecessary to cut bricks.

Fig. 214.

The bar is curved to fit the soffit of the arch, and in order to prevent it from straightening under the thrust a small bolt is sometimes passed through it and secured to a plate on the crown of the arch.

Flat turning bars have been advocated as tending to draw the jambs together instead of thrusting them out, but they are seldom if ever adopted.

The interior of the jambs of chimney breasts should always be filled in solid.

Hearths are stone flags about $2\frac{1}{2}$ inches thick, placed so as to catch the droppings from the grate. The *back hearth, bh* Fig. 213, covers the space between the jambs of the chimney breast.[4] The *front hearth, fh*, rests upon the trimmer arch described on p. 131.

Bond of Chimney Shafts.—It has already been mentioned that the external walls of chimneys should be 9 inches thick, at least until the shaft has passed through the roof; they are better if built in cement.

[1] Or Chimney-bar.
[2] See also London Building Act (1894), Rules as to Chimneys and Flues.
[3] Or Caulked.
[4] Solid concrete hearths are frequently used instead of stone hearths on brick trimmer arches.

Such a thickness is almost necessary for safety within the building, where the woodwork of the roof and skirtings is frequently brought up against the chimney.

It is, moreover, an advantage to have a thick wall round the chimney shaft, even in the open air, as it tends to keep the flue warm. A thin wall is soon partially destroyed by the weather, and admits cold air to the flue, causing it to smoke.

WHOLE-BRICK EXTERNAL WALLS, ENGLISH BOND.—Figs. 215, 216, give horizontal sections of two courses of the chimney in Fig. 202, just before it emerges from the roof. It has an exterior wall 9 inches thick built in English bond.

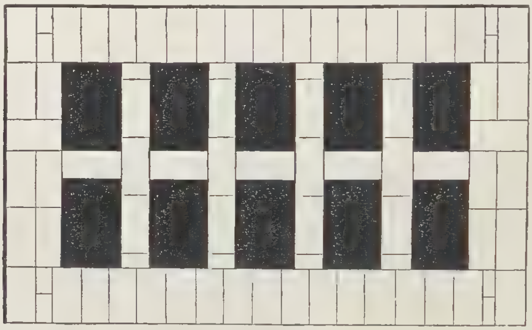


Fig. 215.

Chimney. Whole-Brick external walls. English Bond.
Fig. 216.

It will be seen that the cross withes are well bonded into the external walls in alternate courses, and the longitudinal withe may also be bonded in either by cutting bricks as at A, or by mitreing as at B.

HALF-BRICK EXTERNAL WALLS, ENGLISH BOND.—In ordinary buildings the external walls of chimneys and chimney breasts

are, for economy, made only half a brick thick throughout, both inside the building and above the roof. Examples of the necessary bond are therefore shown in Figs. 217, 218, though such thin external walls are objectionable for the reasons already stated.

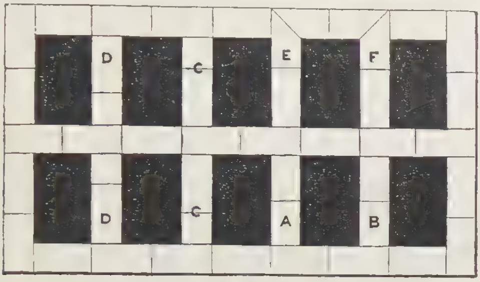
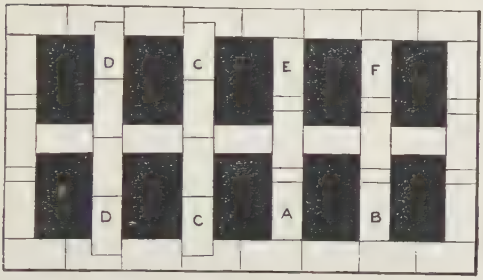


Fig. 217.



Chimney. Half-brick external walls. Stretching Bond.
Fig. 218.

STRETCHING BOND.—These $4\frac{1}{2}$-inch external walls are sometimes built in stretching bond; such a bond, however, carried out in the ordinary manner, leaves the cross withes quite detached from the side walls, as are the withes A B in Fig. 218.

This may, however, be avoided by causing the withes in alternate courses to penetrate the side walls to the depth of $\frac{1}{4}$ brick or $2\frac{1}{4}$ inches, as shown in withes C C, D D, Fig. 218, or by cutting the bricks forming the ends of the withes to a mitre, as at E F, Fig. 217, so as to fit the adjacent bricks in the external wall, which are similarly cut.

In both these arrangements the bricks are not allowed to show on the face of the external wall, as headers would interfere with the appearance of the stretching bond.

HALF-BRICK EXTERNAL WALLS, FLEMISH BOND.—The external walls of chimneys may very conveniently be built in Flemish bond as shown in Figs. 219, 220. It will be noticed that there is no elaborate cutting of bricks, the bond is perfectly symmetrical, and the withes are admirably united with the external walls.

If the flues at one end were required to be 14 inches square, as for a

very large kitchen chimney, $\frac{3}{4}$ bricks would be used instead of *c c*, and half bricks or false headers inserted at *h h*.

The exact arrangement of bond in a chimney must depend upon the size, shape, diameter, and arrangement of the flues, the thickness of the outer walls, the bond adopted in the building, and other particulars depending upon circumstances.

It would of course be impossible to illustrate even a very small portion of the various arrangements required by different combinations of the above particulars.

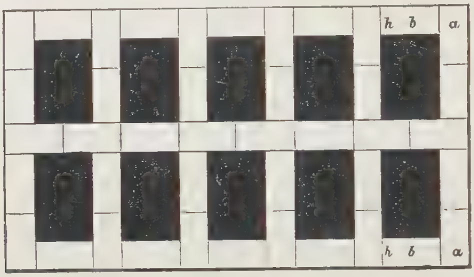


Fig. 219.

Chimney. Half-brick external walls. Flemish Bond.

Fig. 220.

Further examples cannot here be given, but it will be good practice to the student to draw for himself the bonds best adapted for chimneys of different forms and arrangements, in doing which it is hoped that he will find the above illustrations a useful guide.

Stone Chimneys.—Chimney breasts in stone buildings are very often built with bricks, which are better adapted than stone for forming the thin withes and walls required, and generally less expensive than sound masonry.

The chimney breasts and flues are, however, frequently built in rubble.

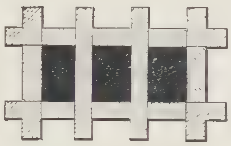
When the chimney passes above the roof it is of course necessary that, for the sake of appearance, it should be of the same material as the walls of the building generally.

Chimneys in rubble are built in a very similar way to those in brickwork; those of cut stone or ashlar are very varied in form and design.

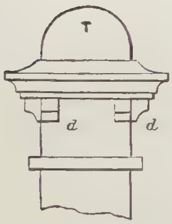
Figs. 221-223 show the plan and elevations of a chimney in cut stone, of a form frequently used.

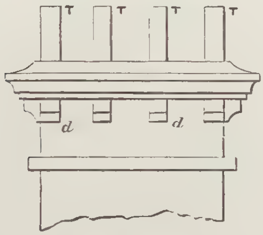
The cap is supported by blocks, *d d*, and surmounted by semicircular "terminals," T, T, which are intended to prevent downdraughts, and to protect each flue from the action of those adjacent to it.

Fig. 221.



Plan.





End Elevation. Fig. 223.

Side Elevation. Fig. 222.

Chimney Flues, especially those in masonry, are frequently formed with earthenware pipes, which afford but little resistance to the smoke, are free from the objectionable corners of brick flues, do not collect the soot, and are easily kept of uniform section throughout; on the other hand, if the internal surface is too smooth, the soot is apt to collect and fall in lumps.

Rendering.—The flues may be rendered inside with Portland cement.

Pargetting.—The ordinary method is, however, to plaster the inside of the flue over with a mixture of one part of lime with three of cow dung; this forms a tough lining with a smooth surface, and not so liable to crack as ordinary mortar.

CORING.—While a chimney flue is being built, it is advisable to keep within it a bundle of rags or shavings called a "sweep," in order to prevent mortar from falling upon its sides; and after the flue is finished, a wire brush or core should be passed through it to clear away small irregularities, and to detect any obstruction that there may be in the flue.

CHIMNEY POTS[1] are frequently placed over flues, to prevent the eddy of wind that would be caused by a flat surface at the top of the chimney.

[1] Sc. *Chimney cans.*

Chapter V.

CARPENTRY.

JOINTS AND FASTENINGS.

General Remarks.—In designing joints and fastenings the carpenter should bear in mind not only the present position and form of the parts he places in contact, but also the changes that will certainly occur from the shrinking and settlement of the timbers, otherwise pressures will come upon parts not intended to receive them, and the pieces will frequently be crushed or split at the points of contact.

The principles which should be adhered to in designing joints and fastenings are laid down by Professor Rankine as follows:—

1. To cut the joints and arrange the fastenings so as to weaken the pieces of timber that they connect as little as possible.
2. To place each abutting surface in a joint as nearly as possible perpendicular to the pressure which it has to transmit.
3. To proportion the area of each surface to the pressure which it has to bear, so that the timber may be safe against injury under the heaviest load which occurs in practice, and to form and fit every pair of such surfaces accurately, in order to distribute the stress uniformly.
4. To proportion the fastenings so that they may be of equal strength with the pieces which they connect.
5. To place the fastenings in each piece of timber so that there shall be sufficient resistance to the giving way of the joint by the fastenings shearing or crushing their way through the timber.

The simplest forms of joints are the best, so that the parts may be fitted with the least possible inconvenience. Double abutments, such as that in Fig. 258, should be avoided, as they are difficult to fit; moreover, when the timber shrinks the whole strain may be thrown upon one of them.

Classification.—JOINTS.—The various forms of joints used in carpentry may be arranged as follows:—[1]

Nature of Joint.	Form of Joint used, and page in which it is described.
Joints for lengthening "ties" or beams in tension	Lapping, p. 94. Fishing, p. 95.
Joints for lengthening "struts" or beams in compression	Scarfing, p. 96.
Joints for lengthening beams under cross strain	Tabling, p. 95.
Joints for beams bearing on beams . .	Halving, p. 100. Dovetailing, p. 100. Notching, p. 101. Cogging, p. 102. Tusk tenon, p. 104. Chase mortises, p. 109.
Joints for beams on posts . . . . Joints for posts on beams	Tenon, p. 103. Joggle, p. 106. Bridle, p. 109.
Joints connecting struts with ties . . Joints connecting struts with posts . .	Oblique tenon, p. 106. Circular, p. 109. Bridle, p. 109.
Strut and beam joints	Mitre, p. 111.
Tie and brace joints	Dovetailing, p. 111. Notching, p. 102.
Suspending pieces	p. 111

FASTENINGS are used for making joints more secure, and may be classified thus:—

Wedges, p. 112.
Keys, p. 113.
Pins . { Wood pins, p. 113. Nails, p. 114. Spikes, p. 114. }
Pins . . { Trenails, p. 114. Screws, p. 114. Bolts, p. 115. }
Straps, p. 116.
Sockets, p. 118.

JOINTS.

Beams are joined in the direction of their length by "lapping," "fishing," and "scarfing."

Lapping.—This consists in simply laying one beam over the

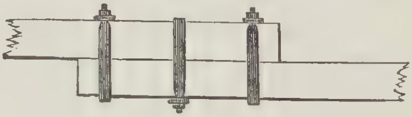


Fig. 224. *Lapping.*

other for a certain length, and binding them together with straps, as shown in elevation in Fig. 224, or, if the joint is to stand a tensile strain, with bolts.

[1] A modification of the arrangement given in Rankine's *Civil Engineering*, p. 453.

Dr. Young says of this joint: "We acknowledge that this will appear an artless and clumsy tie-beam, but we only say that it will be stronger than any that is more artificially made up of the same thickness of timber."

Fishing.—The ends of the pieces are butted together, and an iron or wooden plate or "*fish-piece*" is fastened on each side of the joint by bolts passing through the beam. Fig. 225 is the plan of a joint fished with wooden plates, and Fig. 228 shows one fished with iron plates.

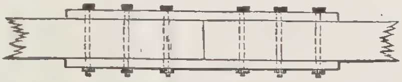


Fig. 225. *Fishing with Timber Plates.*

The bolts should be placed chequerwise (see Fig. 234), so that the fish plates and timbers are not cut through by more than one bolt hole at any cross section.

When subjected to tension, the chief strain comes upon the bolts (which are but slightly assisted by the friction between the "*fish-pieces*" and beam), these are loosened by the slightest shrinkage of the timber, and they then press upon the fibres, crush them, and thus cause the joint to yield.

This dependence upon the bolts may be lessened by indenting or "*tabling*" the parts together, as at T T, Fig. 226, or by inserting keys, *k k*, but these arrangments decrease the section and strength of the beams.

This is a very strong form of joint, but clumsy in appearance. It is useful for concealed work, or in rough and temporary structures, such as scaffolds.

When a beam is fished to resist compression, there should be plates on all the four sides.

A fished joint is manifestly unsuited to resist a cross strain.

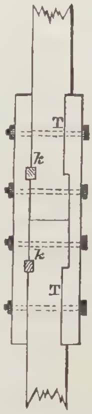


Fig. 226. *Fished Joint showing Keys k k, and Tabling T T.*

The strength of fished joints in tension depends

(*a*) On the effective sectional area of the fish plates being together equal in tensile strength to the effective sectional area of the beam.

(*b*) On the sectional area of the bolts being sufficient on either side of the joint to resist shearing.

In practice it is usual to take the sectional area of the bolts as equal

on either side of the joint to at least $\frac{1}{5}$ the effective sectional area of the tie.

(*c*) On placing the bolts in such a way, and at such distances, from the ends of the fish plates and butting ends of the timbers—that they will not draw through them—by shearing out the wood in front of them.

(*d*) On giving the bolts such bearing area as will prevent their cutting their way through the timbers on the fish plates. It is in this way that fished ties are most liable to yield.[1]

Scarfed joints are often fished with iron plates to assist the scarf (see Fig. 230, etc.) These plates also serve to protect the wood from being crushed by the bolts. They are sometimes turned down at the ends into the timber, so as to assist it in resisting tensional strains. It has been recommended that the indented ends should not be opposite to one another, as in Fig. 232, for in that position they cut into the timber at the same cross section, and weaken it more than if they are placed as in Fig. 234.[2]

Scarfing.—General Remarks.—Figs. 228 to 236 show sections of several forms of "scarfs"[3]—taken chiefly from Tredgold's work on Carpentry. It will be seen that they present a neater appearance than fished joints, inasmuch as the pieces are cut to fit one another, so that the resulting beam is of the same thickness throughout.

Much ingenuity has been expended in devising scarfs of very intricate form, but the simplest are the best, as they are the easiest to fit accurately together.

Fig. 227.

Many of the intricate forms given in books will be found to be useless upon being tested by the following principles laid down by Tredgold:—

When two pieces of timber are tabled together, as shown in Fig. 227, if a tensile strain in the direction of the arrow comes upon the joint, it is evident that it would tend to shear off the pieces *a h i c*, *c i f d*, by sliding them along the grain, also to crush the ends of the fibres at *c i*, and further to tear the beams asunder at *b c*, *i k*.

As "the weakest part is the strength of the whole," there would be no use in making *b c* wide enough to resist tearing if the piece *a h i c* were so weak as to be dragged off, and *vice versa*.

In such a scarf, then, the strength of *c i* to resist compression, that of *c i f d* and *c i h a* to resist shearing, and of *b c* or *i k* to resist tearing, should all be equal.[4]

The bearing surfaces of indents which undergo compression, should be at right angles to the direction of the

[1] Seddon's *Builders' Work*.
[2] *Ibid.*
[3] Sc. *Scares*.
[4] See Tredgold's Rules, page 62.

compressing force: there is a temptation to make them oblique (see Fig. 229), in order to hold the pieces together close side by side. This is not an objection when the beam is exposed only to tensile strains, but under compression, the angular point of one piece tends to tear or split the other.

In the succeeding figures it will be noticed that the scarfs are frequently aided in their resistance to strains by the use of fish plates, of hard wood keys, and of wedges. In applying these accessories to scarfs, their strength must be proportioned to that of the parts of the scarf itself—*e. g.* the strength of the fish plates (after being weakened by the holes for the bolts) must be equal to that of the beams to be united; and the resistance to shearing afforded by the keys must be equal to that of the portion of the scarf on either side.

DIFFERENT FORMS OF SCARFS.—From the above remarks, it will be manifest that the form of the scarf should be varied to suit the nature of the strain it is to bear.

Scarf to resist Compression.—Fig. 228 shows in elevation a very simple form of scarf, evidently well adapted to resist compression. The bearing surfaces are large, and perpendicular to the compressing force. Its form does not help it to resist tension. Under a tensile strain it would depend entirely upon the shearing strength of the bolts to hold it together. Nor is it adapted for a cross strain, which would bend the iron plates and tear out the bolts.

Fig. 228. *Scarf to resist Compression.*

A modification of this scarf is sometimes formed like that in Fig. 232, but when intended to resist compression only, the keys *k k* are not required.

Any scarf containing oblique bearing surfaces is not adapted to resist compression, for reasons already given.

Scarf to resist Tension.—The scarf shown in Fig. 229 is often

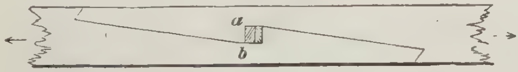


Fig. 229. *Scarf to resist Tension.*

used for beams to resist a tensile strain. It will hold without the aid of bolts or straps, but the triangle *a b c* offers a weaker resistance to the pressure of the wedges than when the joint is left square, as in Fig. 231.

A splayed angle or "sally" is formed at each end to hold the pieces together side by side.

The oblique surfaces of this scarf make it ill adapted to resist compression, and the angles which receive the splayed ends are liable to be split by their pressure.

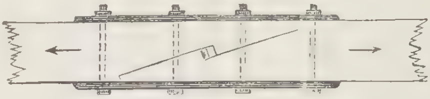


Fig. 230. *Joint fished with Iron Plates, and Scarfed to resist Tension.*

Fig. 230 is a modification of the last, often used in preference.

Scarf to resist both Tension and Compression.—The form of scarf shown in Fig. 231 is well adapted to resist both tension and compression, even independently of bolts and plates.

It is evidently weak in cross section, on account of the timber being so much cut away, and therefore it is not fit to withstand a transverse strain.

Fig. 231. *Scarf to resist Tension and Compression.*

The wedges shown in the centre are most useful when bolts are to be added, in which case they bring the parts of the joint up to their eventual position before the bolts are inserted, so that there may be no cross strain upon the latter.

Fig. 232 shows a modification of the last, in which the tabling

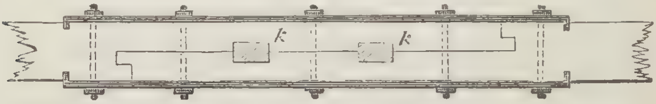


Fig. 232. *Scarf with Keys k k to resist Tension and Compression.*

is avoided, and the necessary resistance to tension is given by means of keys of hard wood, *k k*, as shown; or pairs of wedges such as that shown in Fig. 231 may be used with advantage.

Scarf to resist Cross Strain.—When a beam is subjected to a

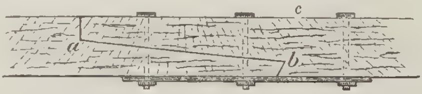


Fig. 233. *Scarf to resist Cross Strain.*

transverse strain, the fibres of its upper part are compressed, and

those of the lower portion distended, as shown in an exaggerated form by the dotted lines in Fig. 233.

In scarfing such a beam, therefore, the indents in the upper or compressed portion should be kept square and perpendicular to the pressure, while those in the lower, or distended part, may be oblique, as they have to resist tension only.

The strength of the scarf is increased by inclining *a b* so as to have as great a thickness as possible at *c b*. The angle at *b* tends to hold the pieces together.

It has been found by experiment [1] that a joint to resist cross strain is stronger when scarfed vertically through its depth, as in Fig. 234, than when the scarf is formed flatwise across its width, as is usually the case.

Fig. 234. *Joint Scarfed vertically and Fished to resist Cross Strain.*

Scarf to resist Cross Strain and Tension.—If, in addition to transverse pressure, the beam is exposed to a strain in the direction of its length, its resistance to tension is afforded by placing a wrought-iron plate over the joint on the lower side as shown in Fig. 235.

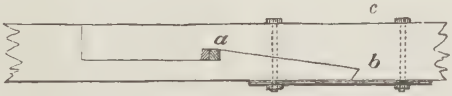


Fig. 235. *Scarf to resist Cross Strain and Tension.*

In this scarf the angle at *a* is rather weak, but the line *a b* is necessarily oblique, in order to get a sufficient thickness at *b c* to resist the transverse strain.

Scarfing Wall Plates.—Fig. 236 shows the usual way of scarfing wall plates. The wedge-shaped portion is technically known as the "calf," or "kerf."

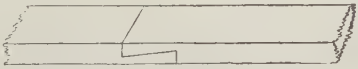


Fig. 236. *Scarfed Wall Plate.*

TREDGOLD'S RULES.—Tredgold gave the following practical rules for proportioning the different parts of a scarf, according to the strength possessed by the kind of timber in which it is formed, to resist tensional, compressile, or shearing forces, respectively.

---

[1] By Colonel Beaufoy. See Barlow's *Strength of Materials*, Art. 68.

In Fig. 227, *c d* must be to *c b* in the ratio that the force to resist sliding or shearing bears to the direct cohesion of the material—that is,

In Oak, Ash, and Elm, *c d* must be equal to from 8 to 10 times *c b*.

In Fir and other straight-grained woods *c d* must be equal to from 16 to 20 times *c b*.

The sum of the depth of the indents should equal ⅓ the depth of the beam.

The length of scarf should bear the following proportions to the depth of the beam.

	Without Bolts.	With Bolts.	With Bolts and Indents.
Hard Wood (Oak, Ash, Elm) .	6 times.	3 times.	2 times.
Fir and other straight-grained woods	12 ,,	6 ,,	4 ,,

Halving of the simplest kind is shown in Fig. 237. Half the thickness of each piece is checked out, and the remaining portion of one just fits into the check in the other—the upper and under surfaces of the pieces being flush. This is a common way of joining wall plates or other timbers, at an angle where there is not room to let the ends project so as to cross one another.

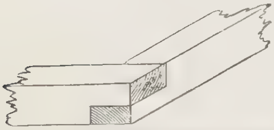


Fig. 237. *Halved Angle Joint of Wall Plates.*

Bevelled Halving.—In this joint the surfaces of the checks are splayed up and down, as shown. If the lower beam is firmly bedded, and the upper beam has a weight upon it, so that the surfaces are kept close together, their splayed form prevents the upper beam from being drawn away in the direction of its length, and greatly strengthens the joint.

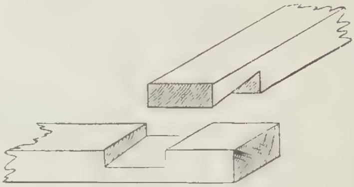


Fig. 238. *Bevelled Halving.*

Dovetail Halving, see below.

Dovetails are so called from the shape of the pieces cut to fit one another.

They are objectionable in carpentry, because the wood shrinks considerably more across the grain than along it. The consequence is, that as *a b* (Fig. 239) shrinks more than *c d*, it is easily drawn partly out, and does not form a firm connection. The joint is, moreover, very weak at the angles *w w*. This is sometimes improved by cutting shoulders to the dovetail, as at *s s* in Fig. 240.

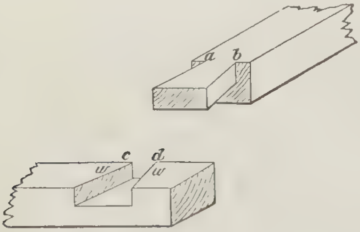


Fig. 239. *Common Dovetail Halving.*

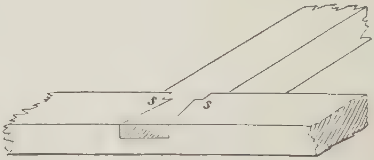


Fig. 240. *Shouldered Dovetail.*

Dovetails are not liable to the first objection mentioned above when the grain in both pieces runs the same way, but in that case, if the timber shrinks, or is strained in the direction of its length, the cheeks are very liable to be split off.

Dovetail Halving (Fig. 239) is a joint in which the dovetail is half the thickness of the piece upon which it is cut, and the notch to receive it half the thickness of the other piece.

See Dovetail Notch, page 102; and Dovetail Tenons, page 106.

Notching.—A beam resting upon another may be notched as shown in Fig. 241.

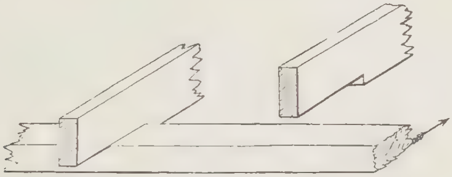


Fig. 241. *Joists notched on to Wall Plate.*

Joists are sometimes thus fitted to wall plates, and when the joists differ in depth the depth of the notches is also varied so as to bring the upper surfaces of the joists to the same level. It will be seen there is nothing to tie the wall plate in toward the direction of the arrow.

In other cases the end of the joist projects, and is left on as shown in Fig. 242; it then grasps the wall plate and holds it in.

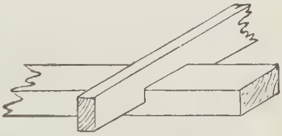


Fig. 242. *Joists notched out to Wall Plates, ends left on full depth.*

Double Notching.—If the notch is required to be a deep one, half of it may be taken out of each timber, as shown in Fig. 243.

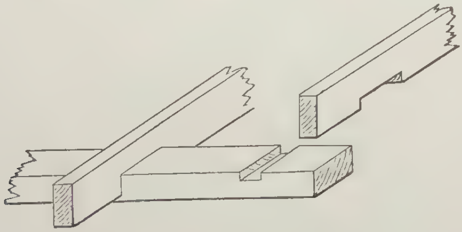


Fig. 243. *Double Notching.*

When each timber is notched to half its own depth, this joint becomes another form of *halving* (see page 100).

Dovetail Notch.—This is a good way of joining wall plates at angles. The inside of the joint is dovetailed, and the outer side is left straight.

Sometimes the joint is tightened up by a wedge driven in on the straight side.

The defect of the dovetail is partly remedied by the grasp the projection of the upper beam has upon the lower.

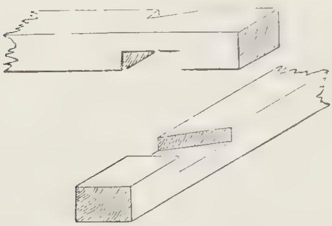


Fig. 244. *Dovetail Notch.*

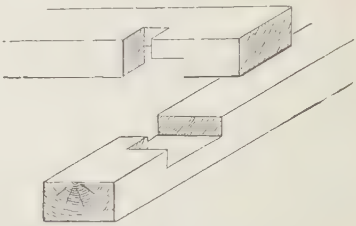


Fig. 245. *Tredgold's Notch.*

Tredgold's Notch.—The form of joint shown in Fig. 245 was recommended by Tredgold as a substitute for the dovetail, but is seldom, if ever, used in practice.

A similar form was recommended by the same authority for uniting the ends of a collar tie to the rafters (see page 111).

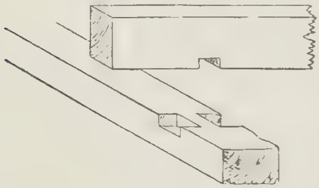


Fig. 246. *Cogged Joint.*

"Cogging," "Corking," or "Caulking."—In this joint (see (Fig. 246), the notch on the lower beam is only partly cut out, leaving a piece or "cog" (like that of a cogged wheel) uncut. The upper beam contains a small notch only wide enough to receive the cog.

"*Cogging*" has the following advantages over *notching*.

The upper beam is kept at its full thickness at the point of support, and is therefore slightly stronger than when notched.

The cog gives the upper beam a hold on the lower, even when its end does not project beyond the latter.

Joists or binders may thus be cogged on to wall plates: if they project beyond the wall plate, as dotted in Fig. 247, the cog may be made broader, but if not, the cog must be narrow and kept toward the inside, so that there may be sufficient substance of timber (x y) on the joist beyond it to resist the strain.

Fig. 247. *Joist cogged on to Wall Plate.*

The above arrangement takes a considerable piece out of the lower beam. When this is supported throughout, as in a wall

plate, it is of no consequence, but, if it spans an opening, it is desirable to weaken it as little as possible.

In such a case, for instance, as cogging joists on to binders (see Fig. 290), or purlins on to principal rafters, the notches in the bearer are made very small, only about an inch or so in depth, and extending inwards about the same distance from the sides of the beam.

Mortise and Tenon Joints. COMMON TENON.—The simplest form of this joint is when a vertical timber A meets a horizontal beam B at right angles.

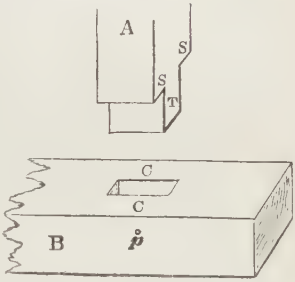


Fig. 248. *Mortise and Tenon.*

In Figs. 248, 249, the *Tenon* (T) is formed by dividing the end of A into three,[1] and cutting out rectangular pieces on both sides each equal to the part left in the middle.

The *Mortise* is a rectangular hole cut to receive the tenon. The sides (C C, Fig. 249) of the mortise are called the *Cheeks*; the surfaces (C C, Fig. 248) on which the shoulders of the tenon rest are sometimes called the *abutment cheeks.*

The springing of the tenon from the beam is called its "*root*" (*r*, Fig. 249); S S are the *shoulders,* and *p* (Fig. 248) the *pinhole,* which is generally placed at $\frac{1}{3}$ the length of the tenon from the shoulder, and is in diameter equal to $\frac{1}{4}$ the thickness of the tenon.

Fig. 249. *Mortise and Tenon. Section.*

If the tenon reached exactly to the bottom of the mortise, it would take its share of the pressure on the post, but it is difficult to make it do so with accuracy, especially as the mortise cut across the grain shrinks more in depth than does the tenon cut along the grain; in practice it is therefore generally made a little shorter than the depth of the mortise, so that the shoulders may bear firmly upon the sill, which is more important.

When a horizontal beam is framed into another, and they are subject to a downward stress, as in the case of joists framed into a girder, the position and form of the mortise and tenon will be determined by other considerations.

It has already been stated (page 98), that when a beam is subjected to a transverse stress, the fibres of the upper portion are

[1] The tenon is not necessarily $\frac{1}{3}$ the width of the timber, but may be made in any proportion so long as it is thick enough to withstand the stress upon it.

compressed, and those of the lower portion extended. In the central line dividing these portions from one another there is neither compression nor extension, and it is therefore called the "*neutral axis*."[1]

The mortise should be placed in the neutral axis of the girder, where the cutting of the fibres will weaken the girder the least, and where the mortise itself, and the tenon within it, will be free from tension or compression.

With regard to the position of the tenon on the joist, the lower down it is the less likely is it to be broken, because the mutual pressures of the butting surfaces above it protect it from cross strain, and also because there is a greater thickness of timber above it to be bent, or torn off, under a breaking weight.

The tenon must not, however, be so low down that there is not sufficient thickness of wood left below the mortise to support it.

It is evidently desirable for the strength of the tenon that it should be as large as possible, but in the ordinary form, above described, this would necessitate a large mortise, and very much weaken the girder. That form, therefore, is not adapted for joints intended to bear a downward strain, for which the "*tusk tenon*," about to be described, should always be used.

TUSK TENON.[2]—This form was devised in order to give the tenon as deep a bearing as possible at the root, without greatly increasing the size of the mortise, and thus weakening the girder.

Fig. 250. *Tusk Tenon through Narrow Girder.*

This object is effected by adding below the tenon (T) the *Tusk* (t) having a *Shoulder* (s) which penetrates the girder to a depth equal to $\frac{1}{6}$ of the depth of the joist; above the tenon is formed the *Horn* (h) the lower end of which projects to the same extent as the tusk.

It will be seen that the strength of the tenon, between h and t is immensely increased as compared with the common form, while the mortise is not made much larger.

The depth or thickness of the tenon is generally about $\frac{1}{6}$ of the depth of the beam.

[1] The neutral axis is coincident with the central line only so long as the *limit of elasticity* has not been exceeded—that is, so long as the timber can recover its former position when the stress is taken off. Beyond this limit its position changes, as explained in Part IV.

[2] Sometimes called *shouldered tenon.*

It may be carried right through a narrow girder and pinned outside, as shown in Fig. 250.[1]

In thicker girders it may penetrate a distance equal to twice its own depth, and is pinned through the top of the girder, as in Fig. 251.

Sometimes tenons are formed with a double tusk, but that form is not to be recommended (see p. 93).

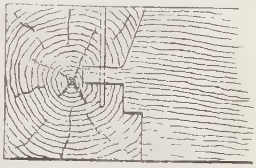


Fig. 251. *Tusk Tenon Joint with Thick Girder.*

The mortise should, for the reasons stated above, be in the neutral axis or central line of the girder, as shown in Fig. 250; practically, however, it is generally placed with its lower edge *on* the centre line, as in Fig. 251, by which arrangement the tenon is in the compressed portion, and the tusk in the extended portion of the girder.

Tredgold recommends that the tenon should be $\frac{1}{3}$ of the depth of the joist above its lower edge. This recommendation cannot always be followed without placing the mortise out of its proper position in the neutral axis, and thus weakening the girder.

For example, when the girder and joist are of equal depth, as in Fig. 250, the tenon must be kept half-way up the joist, as shown, or the mortise would be below the neutral axis—would cut the extended fibres of the girder, and weaken it.

Again, in some cases the relative position of the girder and beam is determined by the space required by other parts of the framing—for instance, in a framed floor (see Fig. 289) more room must be left above for the bridging joists than below for the ceiling joists. This necessitates the tenon being higher, to bring it into the neutral axis of the girder.

In every case it should be considered whether the girder or the joists can best afford to be weakened; if the former has an excess of strength, the tenon may be kept low, so as to strengthen the joist; but if the joist has more strength to spare than the girder, the mortise should be in the neutral axis of the latter, even though the tenon may be high up on the joist.

In practice it more frequently happens that the joists, rather than the girders, have an excess of strength; so it is usual with carpenters to place the mortises with their lower edges on the neutral axis, and to let the position of the tenons on the joists be arranged to suit them.

Double Tenons are often used in joinery (see Part II.), but should be avoided in carpentry, as they weaken the timber into which they are framed, and both tenons seldom bear equally, so that a greater strain is thrown upon one of them than it is intended to support.

[1] The hole in the tenon is made as shown slightly larger (in the direction of the length of the tenon) than the wedge, so that the latter when driven in may draw the beams tightly together.

STUB TENON (or *joggle*) is a very short tenon, used where it is only required to prevent lateral motion—for example, to keep a post in its place upon a sill.

HOUSING is a term used when the *whole* of the end of one piece of timber is let for a short distance—or "housed"—into another, thus the end of the rail is housed into the post in Fig. 252. The "housing" is shown in dotted lines (see Joinery, Part II.)

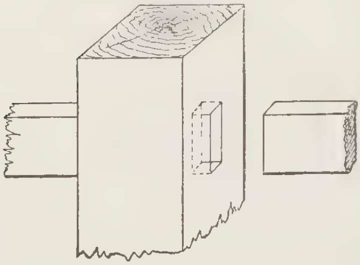


Fig. 252.

DOVETAIL TENONS are those in which one side of the tenon is splayed so as to form half a dovetail, the other side straight. The mortise is also splayed on one side, and is made rather wider than the tenon, which is placed in position, pressed well up against the dovetailed side of the mortise, and then secured by a wedge driven into the interval left on the straight side.

NOTCHED TENONS have one side notched and the other straight; one side of the mortise is also notched to correspond, and the tenon secured by a wedge on the other side.

OBLIQUE TENONS.—When timbers are joined at an angle other than a right angle the tenon has to be modified in form. If constructed as in Fig. 253, it would be very difficult to work the mortise to receive it; moreover, the long tenon would have a tendency to tear up the joint in case of any settlement of the inclined beam; and further, it would be almost impossible to get the tenon into the mortise when the pieces to be joined formed part of a system of framing.

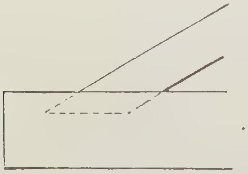


Fig. 253. *Oblique Tenon, bad form.*

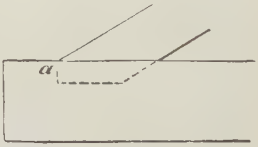


Fig. 254. *Oblique Tenon.*

These evils may be remedied by cutting off the end of the beam, as shown at *a*, Fig. 254.

This is the simplest mortise and tenon for oblique joints, but the only resistance it affords is that offered by the strength of the tenon, which is liable to be crushed, and would in large carpentry

works be quite insufficient to meet the heavy strains that might come upon it.[1]

To remedy this, the cheeks of the mortise are cut down, as in Fig. 255, to the line *d b*, so that while the tenon is retained to prevent lateral motion, the whole width of the beam itself presses against the abutment *a d*, by which a much larger bearing surface is obtained.

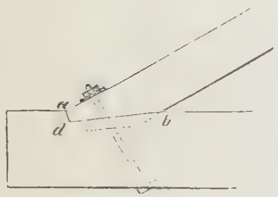


Fig. 255. *Oblique Tenon Joint with Bolt at foot of Principal Rafter.*

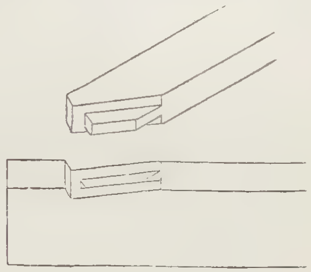


Fig. 256. *Oblique Tenon and Mortise, for Joint between foot of Principal Rafter and Tie Beam.*

Figs. 255, 256 show the joint as frequently constructed for the junction of a rafter and tie beam. Tredgold recommends that the depth *a d* should be greater than half the depth of the rafter, and at right angles to *d b*. It is generally kept shallow from a fear of weakening the tie beam; except for this reason, the deeper *a d* is made the better, and it is often cut perpendicular to the upper surface or "back" of the rafter, as shown in Fig. 255.

The joint in Fig. 257 is a modification of the last.

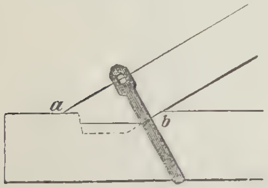


Fig. 257. *Oblique Tenon Joint at foot of Principal Rafter, with Strap.*

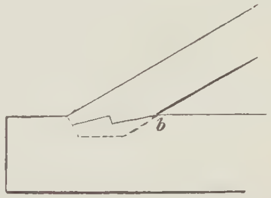


Fig. 258. *Oblique Tenon Joint with Double Abutment.*

Fig. 258 shows a joint with a double abutment. This joint is very difficult to fit with accuracy, and is open to the objections stated at p. 93, but it is sometimes used when the angle of the joint is very oblique, and when there is consequently a large bearing surface.

In putting such joints together they should be left slack at *b* so as to allow for settlement of the framing.

[1] From Newland's *Carpenter's and Joiner's Assistant.*

As the piece of the tie beam beyond the foot of the rafter would have to be left inconveniently long to prevent its being shorn off, it is relieved of some of the pressure, and the joint is secured by means of a strap or bolt, which also serves to keep the rafter in position. The relative merits of these fastenings are pointed out at page 116.

In framing an inclined beam into a post either at its head or foot a tenon joint is used.

It is advantageous to make the head of the post larger (as shown at X in Fig. 259), so as to get an abutment square to the inclined beam.

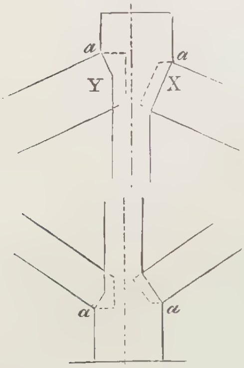


Fig. 259. *Tenon Joints at head and foot of King Post.*

If the head of the post be not large enough to afford the square abutment, it may be cut as at Y.

The tenon should be made, if possible, the whole depth of the inclined beam, but in cases where the top of the post is cut off close to the back of the rafter, as in some roofs (see Fig. 260), the tenon is necessarily made narrower in order to leave some wood on the post above it to form a strong upper cheek to the mortise.

In all cases the joint should be left a little open at *a*, so that when the framing settles it may not bear too severely upon the angle at the top of the rafter.

The same remarks apply to joints at the feet of posts. (See the lower part of Fig. 259.)

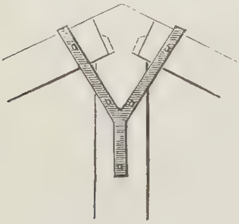


Fig. 260.

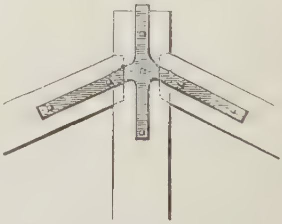


Fig. 261.

Tenon Joints at head of King Post, with Straps.

When the extremities of the post cannot be enlarged the inclined beams may be tenoned into it, as in Fig. 260. It will be seen that this arrangement weakens the post, and reduces the size of the tenon. Whereas the form in Fig. 261 gives a very inclined abutment.

Many other positions in which the mortise and tenon are applicable will be seen in the different examples of framing throughout these notes.

Chase-Mortises, sometimes called PULLEY-MORTISES.—If a piece of timber has to be framed in between two beams already fixed, it is evident that the tenons could not be got into ordinary mortise holes.

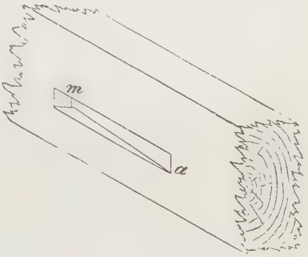


Fig. 262. *Chase-Mortise.*

To enable the cross-piece to be fixed a chase is cut, as shown in Fig. 262, leading to the mortise, *m*, and the cross-piece is first held obliquely until the tenon enters the end of the chase at *a*, whence it is slid along into its place at *m*.

It may sometimes be necessary to make a vertical chase-mortise in a horizontal beam. This should, however, be avoided if possible, as it cuts through so many fibres. The mortise should be parallel to the grain of the timber.

Circular Joints.—Circular joints, especially for very heavy framework, have been recommended by Tredgold, Robison, and other writers, but theoretically they are not to be defended, and practically they are seldom, if ever, used.

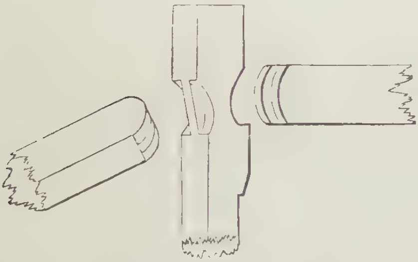


Fig. 263. *Circular Joint for head of Queen Post.*

Fig. 263 shows the circular joints proposed by Tredgold for the head of a queen post with rafter and straining beam framed into it.

Bridle Joints are a sort of converse of the mortise and tenon. The simplest form, that for a post resting on a sill, is shown in Fig. 264.

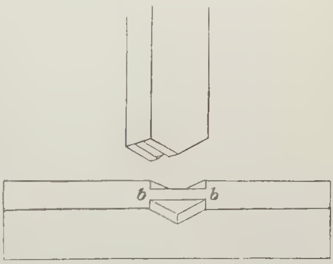


Fig. 264. *Bridle Joint between Post and Sill.*

It will be seen that a kind of mortise is cut in the post to fit the bridle, or projection (*b b*), left upon the beam.

Figs. 265, 266 show a bridle joint for the junction of the foot of a rafter with a tie beam. A similar joint may be used when the head of the rafter meets the king post. Such a joint, with the peculiarity of a circular abutment, is shown in Fig. 263.

The bridle joint is sometimes made use of in practice, and is strongly recommended, in all its forms, by Tredgold, on

the ground that every part of it can be thoroughly seen into before it is put together, and can therefore be more easily fitted than the mortise and tenon.

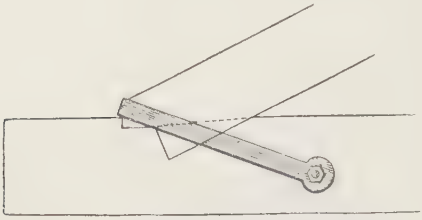


Fig. 265. *Bridle Joint with Strap at foot of Principal Rafter.*

The width of the bridle should not, if possible, exceed $\frac{1}{5}$ of that of the beam, otherwise the cheeks, or pieces which fit on each side of it, will be weak, and liable to be wrenched off by a slight lateral pressure.

Fig. 265 is the elevation of the foot of a principal rafter united to the tie beam by a bridle joint. Fig. 266 shows the timbers detached so as to make clear the construction of the joint. The joint in Fig. 265 is assisted by a heel strap, for a description of which see p. 116.

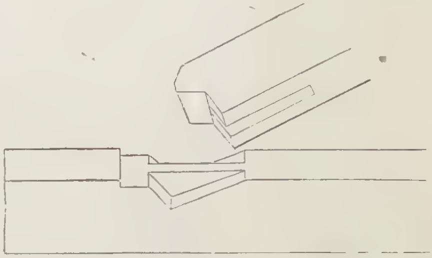


Fig. 266. *Bridle Joints for foot of Principal Rafter.*

Post and Beam Joints.—A post, either upon or under a beam, may be kept in its place by a joggle, or stub tenon (as described at p. 106); but, as there is some danger of the shoulders of the tenon bearing unequally and thus reducing the strength of the post, the angular bridle joint (Fig. 264) is recommended by Tredgold as being more easily fitted.

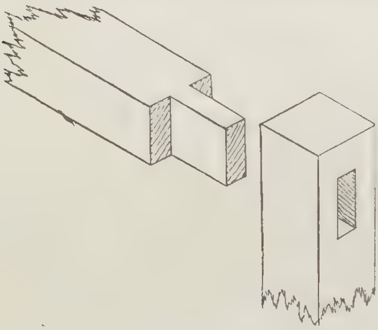


Fig. 267. *Vertical Mortise and Tenon for Joint between Post and Beam.*

It has been proposed that the lower end of the post should be formed with a circular abutment, but this has been proved by experiment to impair its strength.

When the beam meets the post at right angles to the side of its head, as in Fig. 267, a vertical tenon may be used, as shown.

If the beam is at an inclination to the post, one of the several forms of oblique joint may be adopted (see p. 106).

Strut and Beam Joints.—In these it is only necessary that the pieces abut firmly, as long as there is no force tending to make them slide off laterally.

A plain mitre joint bisecting the angle, as at *a*, is preferable to any more complicated form, such as that at *b*,[1] which tends to produce unequal pressures, and to injure the timber.

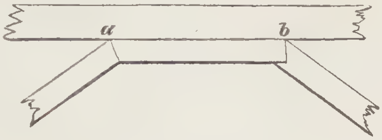


Fig. 268. *Strut and Beam Joints.*

This form of joint is frequently rendered more secure by a cast-iron shoe formed to receive the ends of the timbers at the angle.

Tie and Brace Joints.—When two pieces of timber, meeting at an angle, are tied together, such as two rafters, united by a collar tie, or wall plates by an angle tie, it is very important that the joints between the ends of the tie and the other pieces should not draw out or yield in any way.

One method of forming such a joint is to cut out of the rafter or wall plate a notch of dovetail form, just sufficiently deep to afford a bearing for the tie to rest upon, a corresponding notch is made in the collar tie, and the joint is secured by a nail or pin driven through it.

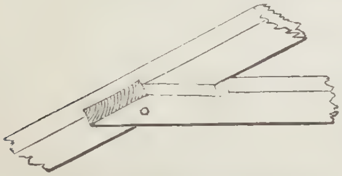


Fig. 269. *Dovetail Tie and Brace Joint.*

The dovetail in this joint is objectionable, for the reasons already given (p. 100), and in order to avoid it, Tredgold recommended a joint similar in form to that shown in Fig. 245.

Suspending Pieces are used for supporting beams below them at one or more points. When adopted in a roof they hang from the point of junction of two rafters, and support the ends of the struts, as well as the tie beam.

The rafters generally abut against the head of the suspending piece, as shown in Figs. 259, 260, 261; but a better arrangement, in many cases, is to make the suspending piece in two thicknesses—the rafters being allowed to abut against one

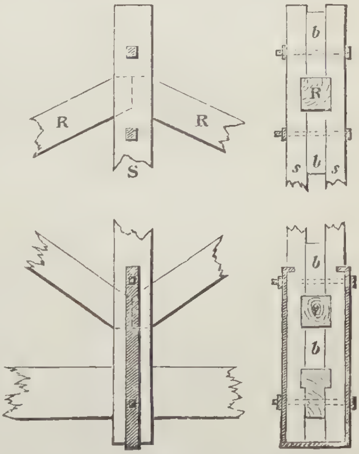


Fig. 270. *King Post formed with double Suspending Pieces.*

[1] The angular notch in the strut, into which *b* fits, is called a *birdsmouth.*

another, a thickness being placed on each side as shown in Fig. 270. R R are the rafters butting against one another; *s s* the suspending pieces, notched upon the rafters, and bolted together through the blocks, *b b*.

The lower end of the suspending piece, supporting a pair of abutting struts and the centre of a tie beam, is shown in the same figure.[1]

Wedging.—In order to keep a tenon tightly fixed, wedges are driven in, as shown in Fig. 271, between the tenon and the sides of the mortise.

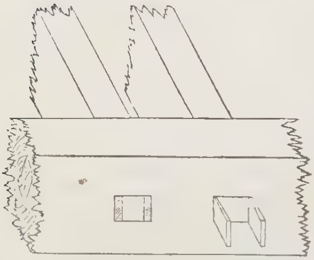


Fig. 271. *Wedged Tenon Joints.*

The mortise should be slightly dovetail-shaped in plan, being wider on the side from which the wedges are inserted, in order to allow room for them to be driven in alongside of the tenon.

When the wedges are on that side of the beam which is in compression they are of use in strengthening as well as tightening the joint.

Wedges are generally sawn out of straight-grained wood, and are dipped in glue or white lead before they are inserted.

Wedges are used in pairs for tightening up joints (see p. 97), being driven inwards so as to take up more room, and thus to force the parts of the joint together. When they are so used, great care must be taken not to drive them too hard, so as to leave the joint with a violent strain upon it.

Fox Wedging.—When a tenon is to be fastened into a mortise in a rail already fixed against a wall, or in any such position that the end of the tenon cannot be seen, it is secured by "fox wedges," thus—

A wedge is inserted in a saw-cut in the end of the tenon, as shown in Fig. 272. The mortise is made slightly wider at the back, and when the tenon is driven home, the wedge entering it splits and spreads out the wood, and makes it fill up the mortise.

With a single wedge there is some chance of splitting the tenon beyond the shoulder. This is thus avoided:—Four or more very thin wedges are inserted, as shown in Fig. 273, the two outer ones being longer than the inner ones. As the tenon is driven

[1] Using timber thus in two thicknesses coupled together has many advantages, and is often a capital arrangement in light roofs.

home, these in succession split off thin pieces, which easily bend,

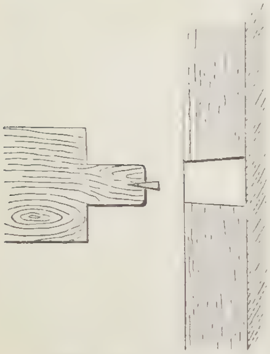


Fig. 272. *Single Fox Wedge.*

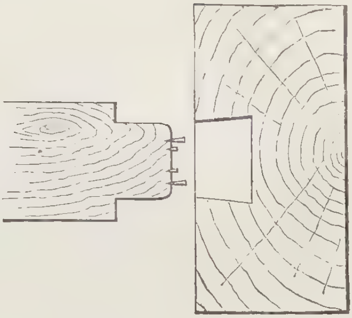


Fig. 273. *Fox Wedging.*

and therefore the splits do not extend too far. The wedges in the figure are rather short, but they should not be very long, as they would then be apt to be broken off in driving.

The enlargement of the back of the mortise should be a little less than the total thickness of the wedges.

Keys (Figs. 226, 232) are wedges of hard wood and curled grain inserted in a joint, and driven gently home, so as to force the parts into the position they will eventually occupy, before inserting bolts, etc. Without this precaution, there would often be a permanent and injurious strain on the latter.

In some cases keys also assist the joint in its resistance to the strain brought upon it (see Fig. 232).

They should be slightly dovetail-shaped in plan, and carefully driven, so as not to injure the fibres of the beam in which they are inserted.

The keys in scarfs are usually made $\frac{1}{3}$ the depth of the timber.

FASTENINGS.

Pinning is the insertion of a pin of hard wood or iron through the timbers forming a joint, to prevent them from separating, or through a tenon, to keep it from drawing out of the mortise. In the latter case, the pin may be through the mortised beam, as shown in Fig. 251, or, if the tenon protrudes beyond the beam, the pin may be outside, as in Fig. 250, care being taken to have a sufficient length of tenon beyond the pin to prevent the end being shorn off by the pin if any strain comes upon it.

Pins should be made from pieces of hard wood, *torn* off from the baulk, in order that they may be of continuous fibre and uniform tenacity.

DRAWBORING is an arrangement for keeping the shoulders of the tenon quite tight up to the cheeks of the mortise, and for tightening pinned joints generally.

The pin-hole is first bored through the cheeks of the mortise. The tenon is then inserted, and the position of the hole marked upon it, after which it is withdrawn, and a hole bored in it a *little nearer the shoulder.* It is then again inserted, and an iron "*drawbore*" pin forced in right through the holes, so as to bring the shoulder up as tight as possible. The drawbore pin is then removed, and the oak pin is inserted.

This operation is condemned by most writers, as it produces a constant and objectionable strain upon the pin and tenon; but it is nearly always resorted to in practice.

NAILS.—Different kinds of nails will be described in Part III.

They are used for roughly and strongly connecting pieces of timber of moderate size, for securing boarding to beams, etc.

SPIKES are large nails used for heavy work.

TRENAILS are pieces of hard wood used, like iron nails, for fastening boards to beams, for forming strong joints, etc., and occasionally, like pins, merely to secure joints formed in some other way.

They are useful in positions where iron nails would rust and injure the work, and where copper nails would be too expensive.

Trenails are generally of oak, cloven from the log, so that the longitudinal fibres may not be cut into.

They are from $\frac{3}{8}$ to $\frac{3}{4}$ inch in diameter, and from 3 to 6 inches long, according to the thickness of the pieces they unite, and slightly taper in form, to facilitate driving.

SCREWS.—The appearance of these is familiar to all, and need not be illustrated.[1]

They are used in positions where the work is likely to be taken to pieces—for example, in fixing the beads of sash frames, which must be removed to repair the sash lines.

Screws are useful also in cases where driving a nail would split the wood, for fixing iron work, and for other purposes where security is required without jarring the joint.

Screws securing work likely to be removed should, if used in

[1] They are described in Part III.

damp places, be of copper or brass, otherwise they will rust, and be difficult to withdraw.[1]

Bolts are often used in order to give additional security to joints, some forms of which, indeed, depend upon them altogether for strength.

They have the disadvantage of weakening the beams through which they pass by cutting the fibres. If the timber shrinks, they become loose, and bruise the grain of the wood where they bear upon it.

Square bolts, with one side at right angles to the pressure upon them, have been found by experiment to cut less into the timber than round bolts.

In many cases bolts are most useful, from the facility with which they can be tightened up, by means of a screw and nut, after the work in which they are used has taken its bearing.

One end of the bolt is generally formed into a solid head, and the other with a screw, on which is fixed a movable nut.

Another way of securing a bolt when it is likely to be removed is by a "slot," or oblong hole, in one of its ends, through which a key or wedge is driven.

The size of bolts should be calculated according to the stresses upon them, and the quality of the iron used. Care should be taken that sufficient timber is left around them to prevent their tearing through in the direction of the strain.

"The following proportions will be found suitable for the bolts and nuts used in carpentry :—

Diameter of head and nut, rose-square or hexagon, from side to side	$1\frac{3}{4} \times$ diameter of bolt.
Thickness of head	$\frac{3}{4} \times$ diameter of bolt.
Depth of nut	$1 \times$ diameter of bolt."

Hurst's *Tredgold*.

The application of bolts to framing of different kinds is illustrated in Figs. 255, 336, and others.

Washers are flat discs of iron placed under the nut of the bolt to prevent it from pressing into and injuring the timber.

Size of washer—
For fir, $3\frac{1}{2}$ times diameter of bolt.
,, oak, $2\frac{1}{2}$,, ,,

Rankine.

The thickness of washers should be equal to half that of the head of the bolt.

Plates are also used to prevent the sharp corners of the nut

[1] An excellent practice is to put goose grease or any non-acid grease upon the screws before driving them.

from pressing into and injuring the timber, and further, in order to strengthen joints by fishing (see Fig. 234, and others).

Straps are often used, instead of bolts, to strengthen or form joints.

They have the great advantage of not cutting through and weakening the timber.

They are generally flat pieces of iron, about $1\frac{1}{2}$ to 2 inches in breadth, and with a thickness depending upon the quality of the iron and the stress upon them.

Straps should be fixed, as nearly as possible, so that the stress may come upon them in the direction of their length. Cross stresses should be avoided as much as possible, but they are necessarily incurred by straps such as that shown in Fig. 261.

HEEL-STRAPS are used to secure the joints between inclined struts and horizontal beams, such as the joints between rafters and tie beams. They may be placed either so as merely to hold the beams close together at the joint (Fig. 274), or so as directly to resist the thrust of the inclined strut, and prevent it from shearing off the portion of the horizontal beam against which it presses (Fig. 352). Straps of the former kind are sometimes called *kicking straps*.

Fig. 274 shows one form of strap for holding the foot of a rafter down to the tie beam. The screws and nuts on its extremities are prevented from sinking into the wood by the connecting plate B, and by them the strap may at any time be tightened up. A *check plate* is sometimes provided, as in Fig. 274, to prevent the strap from cutting into the under side of the tie beam, as in Fig. 277.

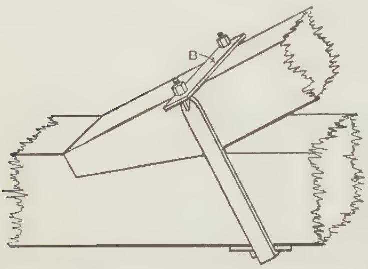


Fig. 274. *Strap for Joint between Rafter and Tie Beam.*

When there is no ceiling, and the strap is therefore visible, the ends of the bearing plate are often rounded, instead of being left square as shown in the figure. The bearing plate is sometimes placed below the tie beam, as in Fig. 277.

A somewhat similar form of strap is shown in Fig. 257. A bearing plate or bar is passed through the holes in the strap across the back of the rafter, and the strap is tightened by wedges driven into the holes.

The straps shown in Figs. 265, 348 are placed so as to take the thrust of the rafter, but are not capable of being tightened up.

A bearing plate with screws and nuts may, however, be used with this form of strap, as shown in Fig. 352.

Straps of this description are sometimes placed so as to clip the rafter by a notch cut a few inches above the toe, so that they partially hold it down as well as resist its thrust (see Fig. 147).

STIRRUP is a name given to a strap which supports a beam, as in Figs. 350 and 270, and to heel-straps of the form shown in Fig. 265. Stirrups, such as that shown in Fig. 270, are sometimes formed with a bearing plate below the supported beam, and tightening screws similar in principle to those in Fig. 274.

Tredgold's rule for straps supporting beams—

If the longest unsupported part of the beam be

10	feet,	strap should be	1	inch wide,	$\frac{3}{16}$	inch thick.
15	,,	,,	$1\frac{1}{2}$	,,	$\frac{1}{4}$	,,
20	,,	,	2	,,	$\frac{1}{4}$	,,

Straps which connect suspending pieces with beams may be formed with a slot, containing gibs and cotters, by which the joint may be tightened, as shown and explained at page 171.

When a strap embraces a built-up beam, it may be welded into a rectangular hoop, and driven on from the end, the beam being slightly tapered to facilitate this; or, if that is inconvenient, it may be made as shown in Fig. 275, the ends passing through an iron head, and being secured by nuts.

Fig. 275. *Strap round Built-up Beam.*

An iron strap bolt suitable for connecting two beams crossing one another is shown in Fig. 276.[1] In both these methods the straps can be tightened by screwing up the bolts.

BRANCHED STRAPS are frequently added to strengthen angle joints. They are subjected to cross strains when the framing settles.

Several forms of these are given (see Figs. 260, 261, 337, 350).

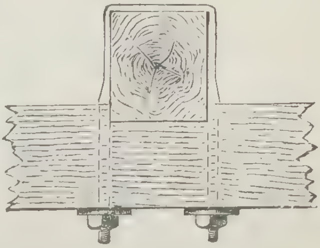


Fig. 276. *Strap Bolt for two Beams crossing.*

Cast-iron Shoes, Sockets, etc., are frequently used to protect the ends of beams from damp or fire (see Fig. 289), and also in themselves to form a joint between two beams.

[1] From Seddon's *Builders' Work.*

TIE-BEAM PLATES.—These may be made of various forms (see Fig. 277, and also Fig. 362. While the plate protects the beam from the damp of the wall, it also forms a corbel to support it, and the upper part may be shaped so as to secure the pole plate above.

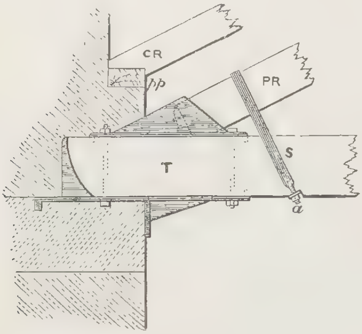


Fig. 277. *Cast-iron Shoe for end of Tie Beam and foot of Rafter.*

SHOE FOR FOOT OF RAFTER.—The foot of a strut or rafter may be received by a shoe instead of being tenoned into the beam (see Figs. 277, 279). The strap shown in this figure is hardly necessary, as the end of the rafter is held down by the shoe.

Fig. 278 shows another form of shoe for a rafter when a tie-rod is used.

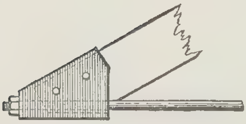


Fig. 278. *Iron Shoe with Tie-rod at foot of Rafter.*

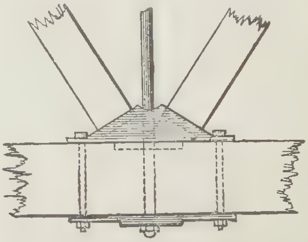


Fig. 279. *Double Shoe for foot of Struts.*

DOUBLE SHOE TO RECEIVE A PAIR OF STRUTS.—Fig. 279 shows a cast-iron shoe adapted to receive a pair of struts in a framing, such as that of the roof shown in Fig. 362).

CAST-IRON HEADS.—Sometimes the tenons at the head of rafters, or the heads themselves, are received in a cast-iron head, as in Fig. 280 (see also Fig. 353 and Fig. 355).

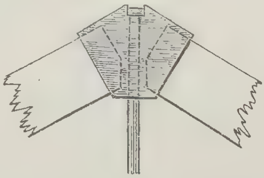


Fig. 280. *Cast-iron Head for Wooden Rafters.*

Chapter VI.

CARPENTRY—(*Continued*).

FLOORS.

WOODEN floors consist of boards supported by timbers.

The timbers of floors of upper rooms frequently have to carry a ceiling for the room below, which has therefore to be considered in the construction of the floor.

Naked Flooring is the term applied to the timbers of the floor without the boards.

Classification of Floors.—There are three classes of floors, viz.

Single floors.
Double „
Framed „

In all these floors the boards rest immediately upon pieces of timber called "*bridging joists*" or "*common joists*."

N.B.—In the sketches illustrating the subject of *Floors* (Figs. 281 to 317) the parts are marked with the distinctive letters given below.

Binders	B	Plastering	P
Boarding	*b*	Pugging	*p*
Bridging joists	*bj*	Strutting	*s*
Ceiling joists	*cj*	Templates	*t*
Fillets for sound boards	*f*	Trimmers	T
Firrings	F	Trimming joists	*tj*
Girders	G	Wall plates	*w*
Lathing	*l*		

Single Floors.—In single floors the "*common*" or "*bridging joists*" span the whole distance from wall to wall, and rest upon the wall plates or templates only.

Advantages.—With a given quantity of timber single floors are the strongest, cheapest, and simplest; they distribute their weight and load very equally over the walls upon which they rest, and hold the sides of the building together.

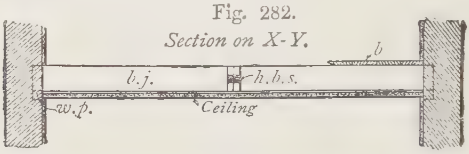
Disadvantages.—The disadvantages of single floors are—

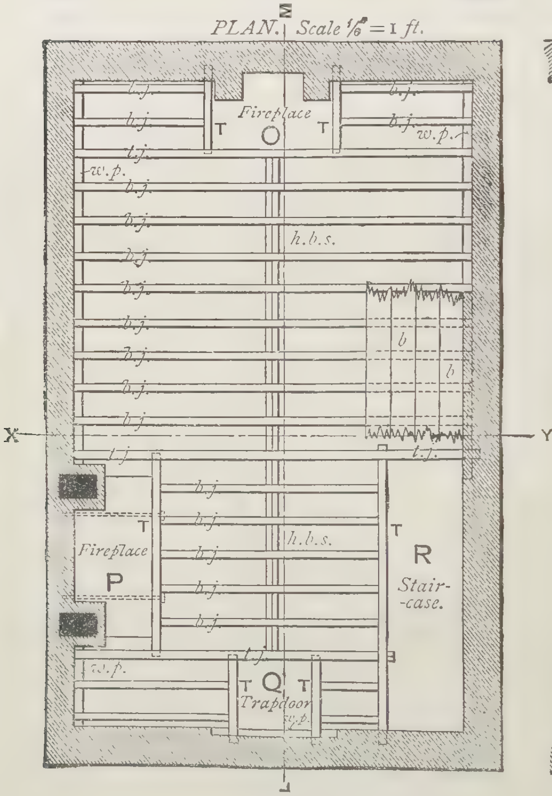
1. When they are used for a span of more than 12 or 15 feet[1] the bridging joists (unless of considerable size) are liable to bend or "sag," and thus to crack the ceiling (if any) below.

2. They require a good deal of "*trimming*" to avoid resting the ends of the joists on flues, fireplaces, etc. (see p. 130).

3. The joists bear equally on all parts of the walls, on piers and openings

Fig. 282.





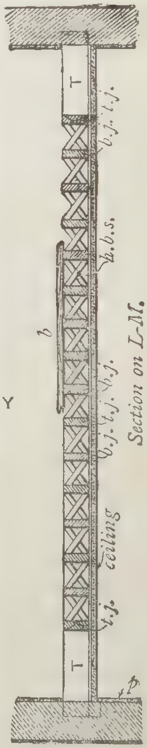


Fig. 281.

Fig. 283.

alike, and thus the jars upon the floor are communicated to the wall even at its weak points.

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[1] Tredgold says that to ensure stiff ceilings the bearing of single floors should not exceed 12 feet, but they are frequently made with a bearing of 18 feet or even more. 18 feet is a safe and usual limit for domestic work.

4. They occasion the use of wall plates, which often have to be fixed *in* the wall (Fig. 295), and are then objectionable.

5. They facilitate the passage of sound from the room below.

This last defect can be remedied or removed by "*pugging*" (see p. 130), and also by keeping nearly all the bridging joists clear of the ceiling, so as to have as few conductors for the sound as possible (see Fig. 297). This latter is, however, an expensive arrangement, as it renders ceiling joists necessary.

In ground floors (see Fig. 284) where there is a space below and no ceiling, intermediate walls ("*dwarf*" or "*sleeper*" walls) or piers are built to support the joists at intervals.

Upper Floor.—Figs. 281, 282, 283 give a plan and sections of a single floor. In this case there are no ceiling joists, the laths being nailed to the under side of the bridging joists, which are all of the same depth.

Plan and Sections of a Single Floor with Trimmed Openings.—Fig. 281 is arranged so as to show various forms of trimming—at O the floor is trimmed *parallel* to the joists to keep clear of a fireplace, at P it is trimmed *across* the joists for another fireplace, at Q it is trimmed to form an opening for a trap-door, and at R for a staircase. Herring-bone strutting is lettered *h.b.s.*; only a small portion of the floor boards are shown, at *b*, in order that the joists and trimmers below may be visible in the plan.

Fig. 297, p. 129, is the section of part of a single floor with ceiling joists, which are supported by the deep joists at the ends of the figure. Only one joist in every four or five is thus connected with the ceiling joists, in order to obtain a more rigid

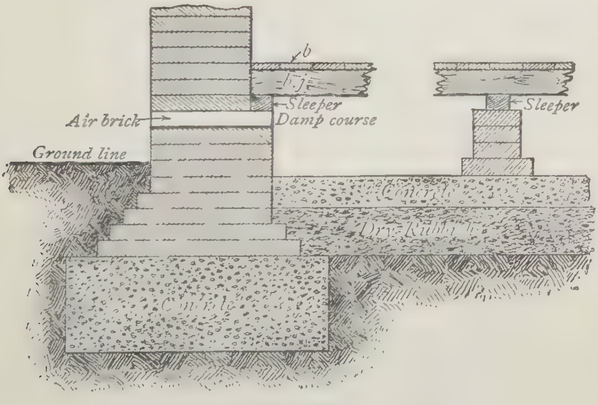


Fig. 284.

ceiling, and also that the points at which the sound can be conducted through the floor may be as few as possible.

Single Floor—Ground Floor.—Fig. 284 is the section of part

of a single floor constructed just above the ground. The concrete under the floor itself is to prevent unwholesome exhalations from being drawn up from the subsoil into the room above. The damp courses are to prevent the damp from rising into the walls.

No trimming is required for fireplaces on the ground floor as the hearthstone is supported by dwarf brick walls called *Fender Walls.*

Double Floors.—In these the *bridging joists*, instead of spanning the whole distance from wall to wall, are supported by intermediate balks called *Binders* (or "*Binding Joists*"), B B, Fig. 285.

Fig. 285. Fig. 287.

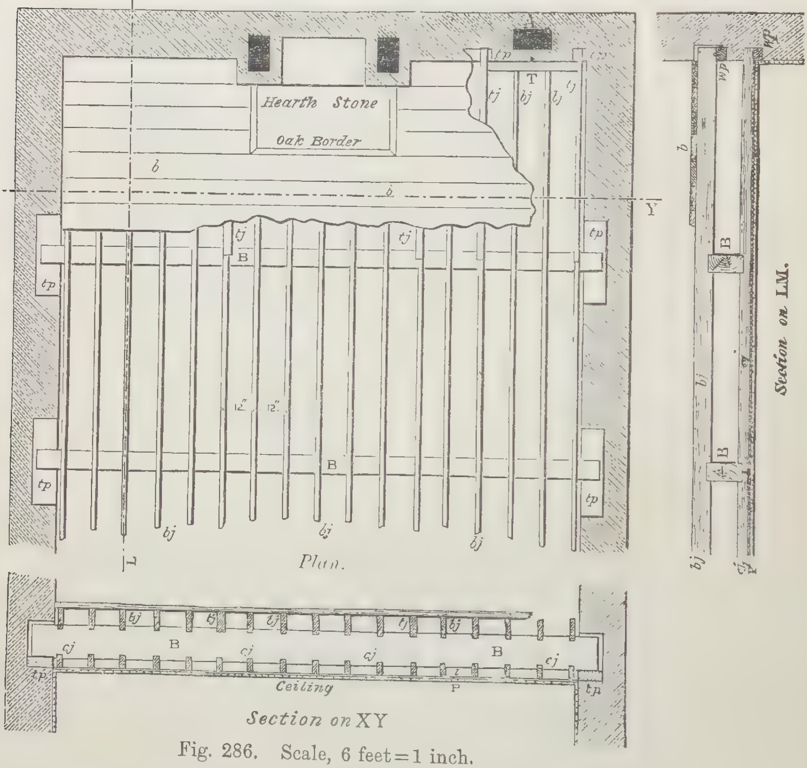


Fig. 286. Scale, 6 feet = 1 inch.

Plan and Sections of Double Floor.

Advantages.—The stiffness of these floors prevents deflection, and secures the ceiling from cracking. They stop the passage of sound from the room below, and the massive binders are of great assistance to the walls of the building in tying them together. Moreover, if binders are placed close to the walls to

carry the ends of the joists instead of wall plates, all timber may be kept out of the masonry except the ends of the said binders themselves.

Disadvantages.—Double floors are in some ways a complicated and bad form of construction. The bridging joists instead of being merely supporters add their own weight to be carried by the binding joists, and being superposed upon them cause the floor to be very deep, which adds to the height of the walls and the cost of the building.

The binding joists bring the whole weight of the floor and its load to bear upon a few points; if the wall is weak and full of openings this is an advantage, for the binders may be carefully arranged so that their ends fall upon the stronger portions of the wall, leaving the weaker parts unloaded.

The space between two binders is called a "*Case Bay*," and that between the binder and wall a "*Tail Bay*."

Tredgold recommends that binders should be fixed from 4 to 6 feet apart, not more than 6 feet. They should be placed so that they may rest on the piers between the windows, not over the openings; they bear either upon wall plates running the whole length of the wall, or upon stone templates of a sufficient length to distribute the pressure.

A plan and sections of a double floor are shown in Figs. 285, 286, 287.

The binders rest on stone templates, *tp*; and the trimming of the joists to clear a flue in the wall is shown at A.

The method in which the floor is finished, with an oak border round the hearthstone, is also shown. A similar border is shown in section in Fig. 299. It is sometimes made, for economy, thinner than the floor boarding, which is checked out to receive it.

The ceiling joists are omitted in plan to avoid confusion. It will be understood that they are attached to the under side of the binders, as shown in section, and run at right angles to their direction.

Framed Floors.—The *bridging joists* in these floors also rest immediately on *Binders*, but the latter, in their turn, are supported by larger balks or "*Girders*."

Framed floors possess, in a still greater degree, the advantages and disadvantages attributed above to Double Floors.

The girders may be of any form or material selected after duly considering all the requirements of the case. (See Part IV.)

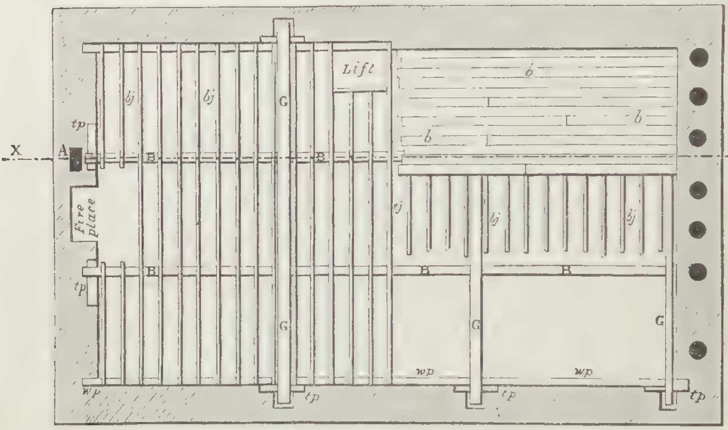
If the girders are simple balks of timber, the binders are framed into them by double tusk tenons. They should be kept as far as possible from the centre of the length of the girders, in order not to weaken them at the points where the strain is the greatest.

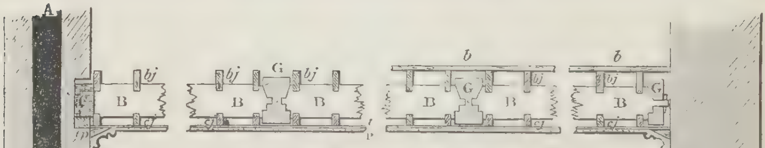
The girders and binders should be as deep as possible, so that the floor may be stiff, not liable to shake or crack the ceiling below. Tredgold recommends that the distance apart of the girders should not exceed 10 feet; their position depends, however, on the plan of the building.

Figs. 288, 289 represent a framed floor in plan and section.

Fig. 288.

Plan. Scale $\frac{1}{10}'' = 1\,ft.$





Section on XY. Scale, $\frac{1}{5}'' = 1\,ft.$

Fig. 289. (Double the scale of Plan.)

Plan and Section of Framed Floor.

N.B.—In Fig. 289 the graining of the binders shown in section is omitted for the sake of clearness.

The girders rest upon templates, and the binders are framed into them as above described. The end of one of the binders, which is close to a flue in the wall at A, is protected against fire by a cast-iron shoe C.

Another way of effecting this would be to allow the end of the binder to rest upon a corbel projecting from the wall.

One end of the floor is supported by a half-girder, in order that it may not rest upon the wall containing flues; if it were not for

these the ends of the binders would rest upon the wall. On the upper side is shown the trimming necessary for a lift.

A great portion of the boarding is broken away to show the timbers below, and the ceiling joists are, as before, omitted in plan to avoid confusion.

When binders are tenoned into a girder they cut into and weaken it considerably, especially when, as is generally the case, the binders are opposite to one another; to avoid this, iron *stirrups* (Fig. 290) are sometimes used to carry the ends of the binders, and so to leave the girder intact.[1]

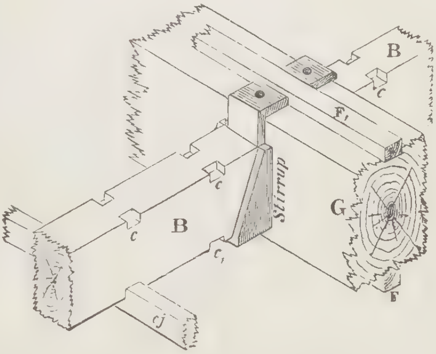


Fig. 290. *Stirrup for carrying end of Binder.*

In framed floors, especially in Scotland,[2] the binders are sometimes omitted, and the girders are of slighter scantling, placed closer together. The ceiling joists are suspended by straps of wood (see Fig. 317, p. 141).

This makes a strong, stiff, and economical floor, but if the bridging joists are simply notched (as they should be) it occupies a considerable depth.

Girders.—When the span of the floor is so great that timber girders of the required scantlings cannot be economically obtained, or are objectionable on account of their bulk or for other reasons, girders of other form and material may with advantage be used.

The difficulty in obtaining sufficiently large timber may be overcome by building up a girder out of small pieces (see p. 144), by trussing beams of lighter scantling (pp. 147-150), or strengthening them by the introduction of an iron flitch plate (Fig. 323, p. 146), or rolled joists (Fig. 324), sandwich-fashion.

IRON BEAMS.[3]—Rolled steel beams (Fig. 462) may with great

[1] The design of such stirrups should be carefully considered and great care taken to provide amply for all tensile, cross-bending, and crushing stresses. They should preferably be constructed in wrought steel or iron.

[2] Newland's *Practical Carpenter's and Joiner's Assistant.*

[3] For the methods of calculation of the strength of Iron Beams the student is referred to Part IV. (*Calculations for Building Structures*). For remarks on British Standard Sections of Rolled Joists, see Part III. (*Materials*).

advantage be used as a substitute for timber girders or binders, for they are less bulky and more durable.

Figs. 291 to 293 show different cases of the application of rolled beams or joists.

In Fig. 291 a rolled beam B is substituted for the binder in a double floor. In Figs. 292, 293, rolled beams are substituted for the girders in framed floors. In Fig. 292 the beam being too deep to be contained within the floor, projects beneath it and is concealed by plastering, which forms part of the panelled ceiling below.

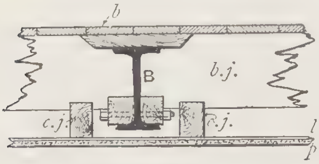


Fig. 291.

Plate Girders.—When still deeper girders are required they may be built up of plate iron as described in Chap. XV. and applied in the same way as the rolled beams shown above.

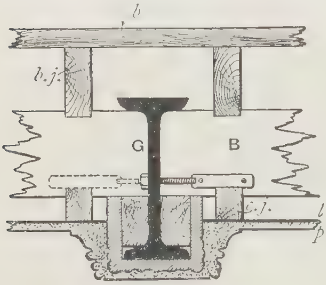


Fig. 292.

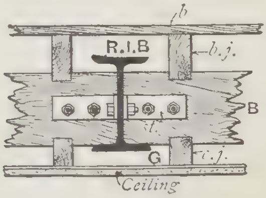


Fig. 293.

General Remarks.—Girders should always be placed so as to have good supports for their extremities.

Those intended to support floors should rest, therefore, on solid walls or piers, not over the windows or other openings.

To ensure this, it is sometimes necessary to lay them obliquely across the room, but an inclined position should be avoided if possible. It is better to provide very strong templates over the openings to carry the girder and throw the weight well upon the piers. Rolled joists are often used for this purpose.

The ends of all timber girders should rest upon stone templates, and be perfectly clear of the masonry.

Girders should be weakened as little as possible by mortises or joints of any kind which cut into them, especially at or near the centre of their length, where the greatest strain comes upon them.

Wall Plates are continuous, or in any case, long pieces of timber built into or upon a wall to support the ends of joists or other bearers.

They distribute the weight thrown upon them by the joists, and give the latter a hold upon the side walls, so that these are tied together.

On the ground floor the wall plates generally rest upon an offset in the wall, as in Fig. 294.

Above also they may rest on an offset if there is a change in the thickness of the wall; or,

They may be built into the wall, as shown in Fig. 295, great

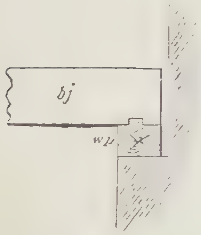


Fig. 294. *Joist on Wall Plate on Offset.*

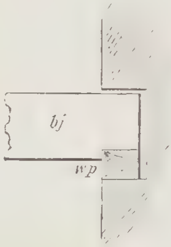


Fig. 295. *Joist notched on Wall Plate built in.*

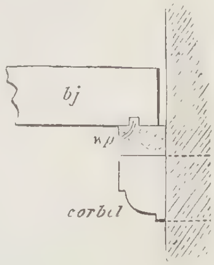


Fig. 296. *Wall Plates supported on Corbels.*

care being taken that there is a free circulation of air round the ends of the joists; or,

They may rest on *corbels* provided for the purpose, as in Fig. 296, or upon a *corbel-course*, thus preventing all danger of decay by contact with the masonry and want of air.

The joists are either simply nailed on the wall plates, or "notched" (Fig. 295) or "cogged" (Fig. 296) upon them.

If the joists are of unequal depths, the notches are varied in depth also, so as to keep the upper surfaces of the joists in the same plane.

Cogging gives the joists a good hold upon the wall plates, so as to tie the walls in, but it is seldom done.

Wall plates are sometimes dovetailed into each other where they meet at the angles of a building, but there are great objections to dovetails (see p. 100), and it is better that they should be halved and bolted.

Wall plates should be in as long pieces as possible, and when two or more pieces are required to extend along the length of the wall they should be scarfed together (p. 99).

Rolled Iron Wall Plates with a raised rib running along their centre line are sometimes used, and are free from many of the drawbacks of wooden wall plates.

Tredgold's Rule for size of Timber Wall Plates—

For a 20-feet bearing,	$4\frac{1}{2}$ inches	by	3 inches.
,, 30 ,, ,,	6 ,,	,,	4 ,,
,, 40 ,, ,,	$7\frac{1}{2}$,,	,,	5 ,,

Templates.—Stone templates are often used instead of wall plates, and have the great advantage of being indestructible by fire or decay. The joists cannot, however, be economically fixed to them, which is a disadvantage.

They should be of hard stone, and in lengths of at least 2 or 3 feet, so as to distribute the weight of the joist and its load over a wide bearing.

Bridging Joists or "Common Joists."—These are generally laid about 12 inches apart "in the clear" (*i.e.* between the side of one joist and that of the joist next to it), or sufficiently near to prevent the deflection of the floor boards. In the best work, however, the joists are laid 12 inches from centre to centre as shown in Fig. 297.

Rough Rule for Depth of Joists.—The rule of thumb for the depth of common joists is to take half span in feet; to this number add 2 for the depth of the joist in inches.

E.g., For a span of 18 feet.—Half this is 9, add 2, which gives 11 inches for the depth.

With the same quantity of timber, the deeper the joists can be made the stiffer and stronger they are. The depth can be calculated by the rules given above or those in Part IV., or obtained from the table, p. 141.

Joists should not be less than 2 inches wide, or they will be split by the nails holding the boarding, especially at the heading joints where four nails come together. In a *trenailed* floor (see p. 114) the joists should be wider. They should never be more than 3 inches wide if they are themselves to carry a ceiling (without the intervention of ceiling joists), as the lower surface of the joists causes a blank space behind the ends of the laths, which interrupts the key for the plastering.

Joists sometimes have a slight curve or "camber" in their length, due often to seasoning—in laying them this should be placed upwards to allow for the "sagging" or drooping which will take place after fixing—any knots should be kept uppermost *i.e.* in that part of the joists that will be under compression when

they are loaded (see Part II.) The whole floor should be laid a little higher in the middle than at the sides of a room. This, however, is difficult to arrange.

Joists are skew-nailed, cogged, or notched on to the wall plates, as described in p. 127. If possible, air space should be left round the end of each.

Strutting.—Joists more than 10 feet long should be *strutted* at intervals of about 6 to 8 feet, to make them stiff and to prevent them from turning over sideways. The struts also add greatly to the strength of the floor, by causing the pressure on the joists to be transmitted from one to the other.

HERRING-BONE STRUTTING[1] consists of small pieces from 2 inches to 3 inches wide and 1 inch thick inserted diagonally and crossing one another between the joists, as shown at *ss* in Fig. 297. They must not be split in nailing them; the holes for the nails must be bored; or two small saw cuts made in each end of the struts to receive them.

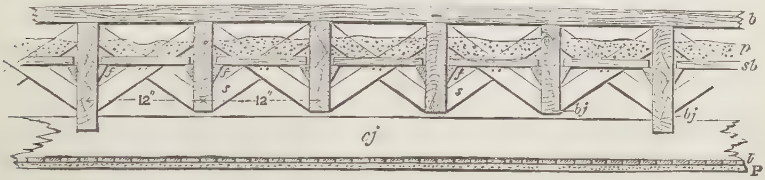


Fig. 297. *Section of Single Floor, showing Pugging, Sound-Boarding, and Herring-bone Struts.*

Sometimes simple pieces of board at right angles to the joists, and fitting in between them, are used instead of the herring-bone strutting.

KEY STRUTTING.—Wooden keys are occasionally used instead of struts. They are mortised through the joists with very small tenons, which must, however, weaken the joists to a certain extent, and they are therefore objectionable as well as being expensive.

Of the above forms the herring-bone struts are the best, as they do not cut into the joists, and they transmit the pressures upon them in proper directions.

Strutting, to be really effective, should be in straight lines along the floor, so that each strut may abut directly upon those adjacent to it.

Tension rods are sometimes passed through the joists at right angles to their lengths so as to bind them together, compressing the struts; this adds greatly to the stiffness of the floor.

[1] Sc. *Dwangs.*

Pugging[1] is plaster (coarse stuff), mortar and chopped straw, or other mixtures laid upon boards fitted in between the joists of a floor to prevent the passage of sound or smell from the room below. It has the drawback of making the floor very liable to rot by preventing the circulation of air.

The "*sound-boarding*"[2] *sb* (see Fig. 297) to carry the pugging, *p*, is supported on fillets, *f*, nailed along the sides of the bridging joists, *bj*, about half-way down.

The fillets are sometimes rectangular in section, about 1 inch by $1\frac{1}{4}$ inch, but are better if cut diagonally out of a piece 2 inches by $1\frac{1}{4}$ inch (see Fig. 297), as they then have a larger surface for nailing.

Dry moss, or a mixture of lime mortar, earth, and smiths' ashes—are sometimes used instead of the plaster; also slag felt, slag wool, turf, plasterers' rubbish, sawdust, tan, dried moss; but all materials likely to decompose are objectionable.

Slips of cork or list along the upper edges of the joists upon which the boards are nailed, are recommended by Tredgold as a means for reducing the passage of sound. Felt or felt-paper over the boards and under the carpet have been used for the same purpose.

Trimming.[3]—It often happens that on account of flues, fireplaces, or from other causes, it is inadvisable to let the ends of the joists rest on particular parts of the walls, and it is necessary that they should be *trimmed.*

The arrangement of the trimming varies according as the joists are at right angles to or parallel to the wall in which the flue or fireplace occurs.

In the former case (see Fig. 299) the joists are stopped short of the portion of wall to be avoided, and tusk-tenoned into a cross beam T, called a *trimmer.*

This trimmer is tusk-tenoned at the ends, and framed in between the two nearest bridging joists bearing on the wall, on each side of the portion to be avoided.

The joists, *tj*, carrying the trimmer, are called "*trimming joists.*" As they have to carry more weight than the other bridging joists, they are made wider.

Tredgold's Rule.—To the width of the common joists add $\frac{1}{8}$ of an inch for every joist carried by the trimmer, and that will give the width of the *trimming joists.*

[1] Sc. *Deafening.*

[2] Sc. *Deafening-boarding*, or sometimes *Pug-boarding.*

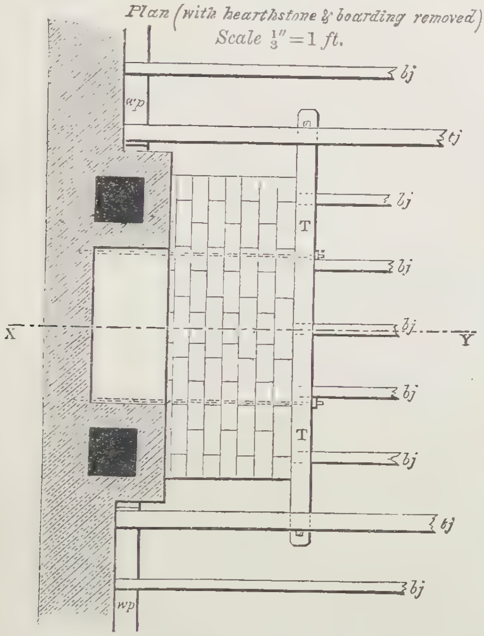
[3] Sc. *Bridling.*

The *trimmer* should be calculated by the same rules as *binders* (see p. 122). This rule refers to the ordinary case in which the joists are all of the same depth, as in Fig. 283. When the trimming joists are deeper than the others, they need not be so wide in proportion.

Figs. 298, 299 show five joists trimmed to avoid a fireplace. A small "*trimmer arch*"[1] is turned from the wall to the trimmer to carry the hearthstone. The length of this arch may with

Fig. 298.

Plan (with hearthstone & boarding removed)
Scale $\frac{1}{3}''=1$ ft.



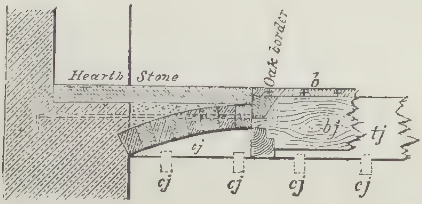


Fig. 299. *Section on XY.*

Plan and Section of Chimney Breast and Hearth showing Trimming.

N.B.—The ceiling joists are omitted in plan to prevent confusion.

advantage be equal to the full width of the chimney breast, and it should, in any case, be at least 27 inches longer than the width

[1] Sc. Bridle.

of the opening of the fireplace, so as to support the hearthstone, which is 18 inches longer than the width of the opening, and to leave room besides for a cradling piece $4\frac{1}{2}$ inches wide at each end, to support the oak border and the ends of the floor boards.

In some cases a filling-in piece is fixed between the trimmer and the wall to support the ceiling joists under the arch. This construction is, for some reasons, objectionable, for it requires a corbel or plate in the wall to support the end of the filling-in piece; and in the illustration given (Fig. 299), it is also unnecessary, for the ceiling joists can be fixed to the trimming joists as shown, and require no support between them. If, however, there are no ceiling joists, the filling-in pieces are necessary to support the laths for the plaster of the ceiling.

When the hearth to be supported is wide and the depth of the floor is not sufficient to afford room for the rise of an arch such as that in Fig. 299, then the trimmer arch may be continued past the crown, as shown in Fig. 300, springing on one side from the chimney breast and on the other from a splayed fillet nailed against the trimmer or trimming joist to form a skewback.

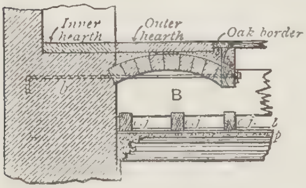


Fig. 300.

When the joists are parallel to the wall in which a fireplace occurs, the trimmer arch is turned against the first continuous joist (in this case called the "trimming joist"), and short trimmers, T, are inserted to carry the trimmed joists between that joist and the wall, in the same way as shown in the trimming for the fireplace in Fig. 281.

In some cases iron pipes are substituted for the timber trimmers T; each rests at one end on the wall, and passes through holes in the short bridging joists which it supports, its other end being supported by passing through a hole in the trimming joists *tj*.

A layer of 3 or 4 inches of Portland cement concrete, supported by wooden fillets extending from the hearth to the trimmer, is sometimes used instead of the trimmer arch. Curved tiles have also been used for the same purpose.

The thrust of the trimmer arch is sometimes counteracted by iron rods built into the wall, as shown in dotted lines. They are more useful when the joists are parallel to the fireplace, in which case the trimming joist against which the arch abuts requires support against bending laterally; the rods, however, are seldom used.

Fig. 285 shows two joists trimmed to avoid the flue at A.

In Fig. 281 is shown the trimming necessary for a trap-door in the floor, and in Fig. 288 a trimming for a lift.

Openings for stairs are trimmed in a similar manner (see R, Fig. 281).

Floor Boards are laid in several different ways.

Plain jointed.[1]—The boards are simply laid side by side, as close as possible (see Fig. 301), a nail or generally two being driven through the boards into each joist.

The inevitable shrinkage of the boards, as at A, will cause openings through this description of floor.

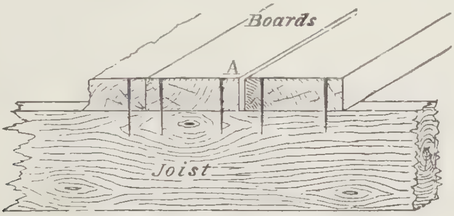


Fig. 301. *Plain Jointed Floor.*

Rebated,[2] of which the section, Fig. 302, explains itself.—Here a considerable shrinkage may take place, as at A, without causing an opening between the boards throughout their depth, but the joint is not an economical one and is seldom used.

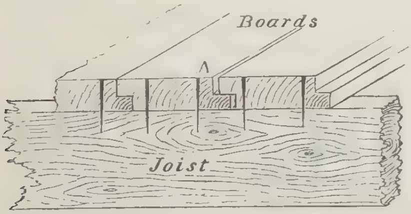


Fig. 302. *Rebated Floor.*

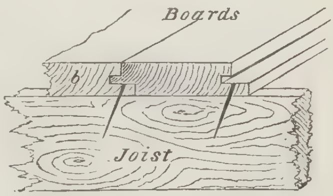


Fig. 303. *Rebated, Grooved and Tongued Floor.*

Fillistered[3] is another name for the joint shown in Fig. 302.

Rebated, Grooved[4] *and Tongued.*—One board can first be nailed

[1] When two boards simply abut against one another, their edges may be "*shot*" or smoothed off with a plane, and their junction is known as a plain or *butt joint.*

[2] *Rebating* or *Rabbeting* is the cutting a rectangular slip out of the side of a piece of wood, as at A in Fig. 302. The re-entering angle left upon the wood is called the *rebate* or *rabbet*, or Sc. *the check.*

[3] Another meaning of the word fillistered is given at p. 136.

[4] *Grooving* or *Ploughing* is the formation of a rectangular groove in a piece of wood to receive a tongue, as in Figs. 305, 306.

as shown at *b*, Fig. 303, and then the other board, upon being slipped into it, will be kept down by the form of joint. Thus the nails are prevented from appearing on the surface of the floor, which is sometimes desirable; the joint is however wasteful of material and troublesome to fit.

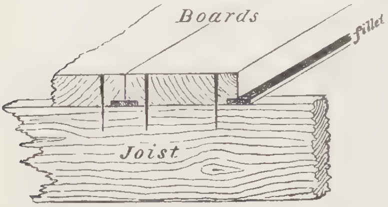


Fig. 304. *Rebated and Filleted Floor.*

Rebated and Filleted.—A rectangular *rebate* is cut out along the lower edges of the boards as in Fig. 304, and the space filled in with a slip or "*fillet*," generally of oak or some hard wood, about $1\frac{1}{4}$ inch or $1\frac{1}{2}$ inch by $\frac{3}{16}$ inch in section.

It will be seen that any opening caused by shrinkage is covered by the fillet, and the floor must be worn down nearly through its whole thickness before the fillet is exposed, so that the joint is an economical one and is easily repaired.

Ploughed and Tongued.—A narrow groove is cut in the side of each board, and an iron or wooden[1] tongue inserted (Fig. 305).

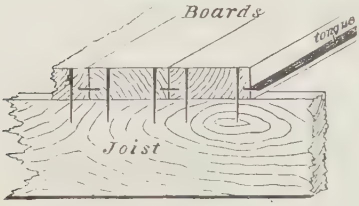


Fig. 305. *Ploughed and Tongued Floor.*

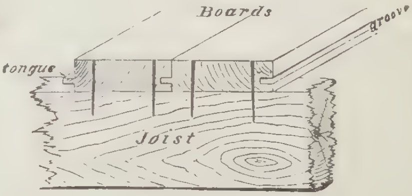


Fig. 306. *Grooved and Tongued Floor.*

It will be noticed that this shares some of the advantages of the filleted joint, but the tongue is sooner laid bare when the floor is much worn. The tongue should be kept lower than the centre of the thickness of the boards, so that as much wear as possible may be got out of them before it is exposed. When wooden slip feathers are used they should have a coat of paint, and iron tongues should be painted two coats, or galvanised to prevent their rusting, swelling, and splitting the wood.

Grooved and Tongued.—In this joint (Fig. 306) the tongue is worked upon one board to fit the groove cut in the other. This is not an improvement on the joint last described; the tongue is necessarily thicker, and thus causes a thinner piece of wood to be

[1] See remarks on slip feathers, Part II. (*Joinery*).

left above the groove. This rots and flakes away if the floor is often washed.

Dowelled.—Small oak dowels are fixed along the edge of one board to fit into holes in the other (see Fig. 307).

The dowels should not be over the joists, but in the spaces between them, so that the edges of the boards are held down and kept flush, at short intervals throughout their length, by the nails at the joists, and by the dowels between.

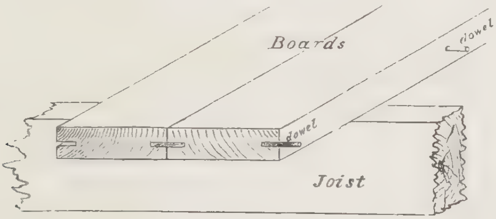


Fig. 307. *Dowelled Floor.*

Dowelled floors show no nails on the surface; only one edge of each board is nailed obliquely, the other being kept down by the dowel.

Of the joints above described, those illustrated in Figs. 301, 302 are used chiefly for inferior floors; that shown in Fig. 304 for warehouses or barracks; those in Figs. 305, 306 for ordinary floors of a high class; and that in Fig. 307 for very superior floors.

The joints in Figs. 302, 303, 306 necessitate the use of a larger quantity of boarding to cover a given surface than when the other joints are adopted.

HEADINGS.—The boards in floors are seldom long enough to go right across the room.

In such a case the joint between the end of one board and the next is called the *heading joint.*

Headings should always fall upon joists, and break joint with one another in plan.

Square Heading.—In this the ends of the boards simply butt against one another, similarly to the side joints in Fig. 301.

Splayed or Bevelled Heading.—The ends of the boards are splayed to fit one another, as shown in Fig. 308.

Tongued Heading.—The ends of the boards are cross-grooved, and laid with a cross-grain wood, or a metal tongue, similar to that shown for the side joints in Fig. 305.

Rebated and Tongued Heading is formed in the same way exactly as the joint shown in Fig. 303, and has the advantages mentioned at page 133.

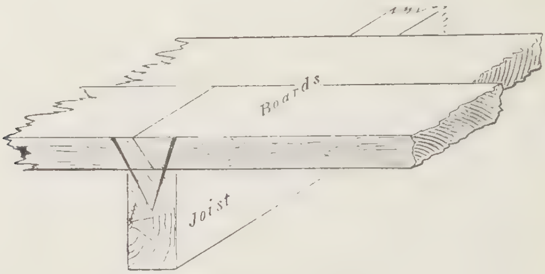


Fig. 308. *Splayed Heading.*

Forked Headings.—In these the ends of the boards are cut into a number of sharp salient and re-entering notches, whose ridges are parallel to the surface of the floor. These notches fit one another, and form a tight joint.

Such joints are sometimes used in oak floors, but they are extremely troublesome and expensive to make, and the point nearest the surface of the floor is very liable to break away, even in hard wood.

Broken Joint Floors.—Sometimes in very common work boards of unequal width are used, so that there are breaks in the longitudinal joints. This occurs chiefly when the floor is laid "folded," as described on page 137.

Straight Joint Floors.—The usual practice is, however, to have the floor boards gauged to the same width, so that their longitudinal joints form straight lines from end to end.

General Remarks on Floor Boards.—Floor boards should be brought on to the ground prepared and planed, generally by machinery, as early as possible after the building is commenced, so that they may be thoroughly seasoned before they are required to be laid.

If not prepared by machinery, the boards should all be brought to the same width, have their edges shot, and be gauged to the same thickness with a fillister plane, which takes out a rebate on each side down to the gauge mark.[1] They are then turned over, and trimmed down to the proper thickness at the points where they cross the joists.

The best floors are those laid with narrow boards (from batten widths down to strips of 3 inches or 4 inches wide), as the shrinkage in each is less, and the joints can be kept tighter.

The boards may with advantage be placed in position, and left a year thoroughly to season before being nailed down.

[1] This operation is called *fillistering.*

However well seasoned they may be, they will always curl up a little after being touched with the plane.

Folded Floors.—Floor boards are generally jammed tightly together as they are laid, by means of flooring cramps, but in common floors they are sometimes *laid folding*, thus :—

Two boards are laid and nailed at a distance apart little less than the width of 3 or 4 boards. These are then put into the space, and forced home by laying a plank upon them, and jumping upon it (see Fig. 309).

Fig. 309. *Laying Folded Floor.*

The boards thus laid together are often of the same length, so that their heading joints fall into one line, and are not properly broken.

Floor Boards in Two Thicknesses.—Known as "*Victoria Floors.*" In very superior floors two layers of boards are frequently used. The lower layer consists of $\frac{3}{4}$ inch deals carefully laid and nailed on to the joists in the usual way. When it is down, the grounds, joinery, skirtings, etc., are fixed, and the plastering completed. After which, the upper layer, consisting of narrow strips 1 or $1\frac{1}{4}$ inch thick, it may be of wainscot oak or of some superior wood, is fixed with dowelled or other secret-nailed joints.

Nailing Floor Boards.—The position of the nails, in the various forms of joint, is shown in the figures.

Fig. 310. Fig. 311. Fig. 312.

Flooring brads (Fig. 312) are generally used for securing the boards to the joists. They are flat-sided nails, which are easily driven in parallel to the grain of the boards without danger of splitting the wood ; their heads being parallel with the grain can be punched below the surface so as to admit of the floor being planed.

They hold better than clasp nails (Figs. 310, 311), and the heads of the latter disfigure the surface of the floor—clasp nails must however be used for edge or secret nailing—as brads would break under the cross strain brought upon them in that position. Holes must be bored for wrought clasp nails or they will split the wood in driving—the labour of boring is saved where cut nails are used.[1]

When the heads of the nails are concealed, as in Fig. 303, the floor is said to be "*secret-nailed.*" This may be effected in the joints shown in Figs. 305, 306 by driving the nail obliquely through the edges of the boards, taking care to clear the tongue or feather.

Secret-nailing is sometimes advisable for polished oak floors, or when the boards are very narrow, as, in the latter case, there would otherwise be a great many nail-heads in the surface.

Screwing down Floor Boards.—Occasionally, especially in oak floors and where boards may have to be removed to get at gas pipes, etc., the boards are screwed down. For oak floors the hole should be countersunk, or a piece taken out about $\frac{1}{2}$ inch deep above the head of the screw and filled in afterwards with pieces of oak to match the floor; this is called "*pelleting.*"

General Remarks on Floors.—The timbers that carry the weight should, as a rule, be laid the narrowest way of the room.

The bearing timbers may be so arranged as to tie in the principal walls, and if the building forms a corner, having two or more external walls, they may be laid in opposite directions in the alternate stories.

All parts of timber built into walls should have clear spaces round them for circulation of air.

Timbers passing over several points of support, such as joists over binders, joists or binders over party walls, and similar cases, should be in as long lengths as possible, by which their strength is greatly increased as compared with what it would be if they were cut into short lengths, just sufficient to span the intervals between each pair of supports. (See Part IV.)

Fixing uniformly loaded timbers rigidly at the ends increases their strength by one half, but this can seldom be done in practice. If the ends are built into the wall they have a tendency to strain and destroy the masonry. The want of a free circulation of air causes the timber to decay, and in any case it soon shrinks and becomes loose.

[1] *S.M.E. Course.*

Tredgold recommends that floors should be laid with a slight rise in the centre (about $\frac{3}{4}$ inch in 20 feet), to compensate for the settlement that will take place in the beams.

All floors near the ground should be ventilated, to secure a perfect circulation of air round all their parts. This is easily done by inserting air bricks in the walls.

For the same purpose openings should be left in the sleeper walls carrying the intermediate wall plates of ground floors.

The ground below the floor should be thoroughly drained, and covered with concrete to prevent damp from rising.

PARQUET FLOORS have their surface formed with small pieces of wood, inlaid to a pattern. They are more the work of a cabinetmaker than of a carpenter, and do not come within the scope of these Notes.

FLOORS OF SHORT TIMBERS.—These consist of very short pieces arranged in different ways so as to support one another, but a description of them would be more curious than useful.

Ceiling Joists [1] are light beams to carry the laths for the plastering of the ceiling. They are fixed to the under side of the bearers of the floor, running at right angles to them; that is, in a Single floor to the bridging joists, in a Double or Framed floor to the binding joists.

They should be 14 inches from centre to centre where double laths are used; if more widely placed than this, the laths are likely to give with the weight of the plaster. With thinner laths the joists must be closer together.

Two inches is the best width for ceiling joists. This is sufficient to nail the laths to. If wider, the under surface of the joist interrupts the key for the plaster.

Notched.—The mode of fixing ceiling joists is generally to notch them and nail them, as shown in Fig. 289.

Chase-mortised.—Sometimes, however, the depth from the ceiling to the surface of floor has to be kept as small as possible, in order to gain space. With this object the ceiling joists may be tenoned in between the bridging joists or binders with chase mortises, formed either as at *x* or as at *y*, Fig. 313. This should, however, be avoided as much as possible, for the mortises weaken the bearers.

Filleted.—Another plan is to support the ends of the ceiling joists (*ff*) upon fillets nailed to the bridging joists, as shown in Fig. 314.

[1] Sometimes called *Raglins* in the North of England.

Where ceiling joists are fixed in between bearers, their lower edges are allowed to come a little below the latter, a *firring*[1] (F in

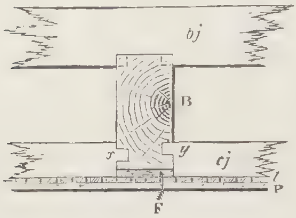


Fig. 313. *Ceiling Joists Chase-mortised into Binder.*

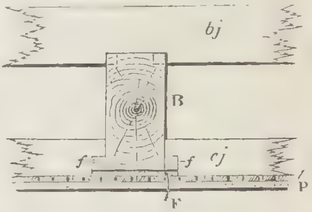


Fig. 314. *Ceiling Joists supported by Fillets fixed to Binder.*

Figs.) not wider than the ceiling joist being attached to the bearer below, so as to afford a key for the plaster.

This is advisable also, because the bearers are sure to sag, and if the under sides of the ceiling joists were flush with those of the bearers, the ceiling would be curved as in Fig. 315 (the curve in which is of course exaggerated); but by allowing them to be

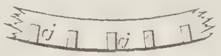


Fig. 315.

Fig. 316.

Ceiling Joists on Sagged Floor.

lower, they can be so arranged (see Fig. 316), that, after the bearer has sagged, their lower surfaces may be in a horizontal plane, so as to form a level ceiling.

In single floors with ceiling joists every fifth or sixth bridging joist is generally made 2 inches or so deeper than the others, and extends below them to carry the ceiling joists (see Fig. 297).

This, as already explained, is to prevent the passage of sound, by reducing the number of points at which it is conducted through the wood.

Ceiling joists should be fixed slightly higher in the centre of the room (about $\frac{3}{4}$ inch in 20 feet), to allow for the inevitable settlement of the floor.

In single floors of small span, the ceiling joists are frequently altogether dispensed with, and the laths nailed to the under side of the bridging joists (see section, Fig. 283).

Ceiling Joists hung by Straps.—Ceiling joists are sometimes hung from the

[1] *Firrings* or *Furrings* are small rough pieces of wood attached to any piece of carpentry to bring its surface up to a required level. Sc. *Ekeings.*

bridging joists in a framed floor, such as that mentioned at page 125 by wooden straps, as in Fig. 317. Thus the separation between the floor and ceiling is more complete, and the sound is less readily conducted.

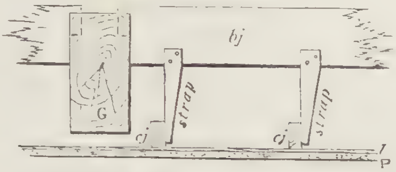


Fig. 317. *Ceiling Joists hung by Straps.*

Brandering.—The ceiling joists to which the laths are nailed somewhat interrupt the key for the plastering of the ceiling. To remedy this, and to obtain a stiffer ceiling, battens about 1 inch square, and from 12 to 14 inches apart, are sometimes nailed to the under side of the joists, crossing them at right angles. These battens keep the laths at a little distance from the joists, and thus give room for the plaster to be squeezed in behind them and form a "*key.*"

Sizes for Floor Timbers.—Tables of Scantling.

Table of the Scantlings recommended by Tredgold for Single or Bridging Joists of Baltic pine for different bearings from 5 to 25 feet—the distance from centre to centre of the joists being 12 inches.

Length of Bearing in Feet.	Breadth, 1½ in.	Breadth, 2 in.	Breadth, 2½ in.	Breadth, 3 in.	Breadth, 4 in.
	Depth in inches.	Depth in inches.	Depth in inches.	Depth in inches.	Depth in inches.
5	5¾	5¼	4¾	4⅜	4
6	6¼	5¾	5⅜	5	4½
8	7¾	7	6½	6¼	5¾
10	9	8	7½	7	6½
12	10	9¼	8½	8	7¼
14	11	10	9½	9	8
16	12¼	11	10½	9¾	8⅞
18	13¼	12	11¼	10½	9½
20	14¼	13	12	11¼	10¼
22	15	13¾	12¾	12	11
24	16	14½	13½	12¾	11¾
25	16½	15	14	13	12

TABLE of SCANTLINGS recommended by Tredgold for BINDING JOISTS of Baltic pine for different spans from 5 to 20 feet when the distance from centre to centre is 6 feet.

Length of Bearing in Feet.	Depth, 6 in.	Depth, 7 in.	Depth, 8 in.	Depth, 9 in.	Depth, 10 in.	Depth, 11 in.	Depth, 12 in.
	Breadth, inches.	Breadth, inches.	Breadth, inches.	Breadth, inches.	Breadth, inches.	Breadth, inches.	Breadth, inches.
5	4¾	3	2				
6	6¾	4	3	2			
7		5½	4	2¾	2		
8	...	7	5	3¾	2¾	2	
10	...		8	5½	4	3	2½
12	...	...		8	6	4½	3½
	Depth, 13 in.	Depth, 14 in.	Depth. 15 in.				
	Breadth, inches.	Breadth, inches.	Breadth, inches.				
14	...	...	...		8	5¾	4½
16	4½	3¾	3¼	...	10¼	7¾	6
18	5¾	4¾	4	...		10	7½
20	7¼	6	4¾	...	...		9½

TABLE of the SCANTLINGS for GIRDERS of Baltic pine recommended by Tredgold for different bearings from 10 to 36 feet —girders 10 feet apart from middle to middle.

Length of Bearing in Feet.	Depth, 10 in.	Depth, 11 in.	Depth, 12 in.	Depth, 13 in.	Depth, 14 in.	Depth, 15 in.	Depth, 16 in.	Depth, 17 in.	Depth, 18 in.
	Breadth, inches.	Breadth, inches.	Breadth, inches.	Breadth, inches.	Breadth, inches.	Breadth, inches.	Breadth, inches.	Breadth, inches.	Breadth, inches.
10	7½	5½	4¼	3½	2¾				
12	10½	8	6	5	3¾	3¼			
14	14½	10¾	8½	6¾	5¼	4½	3½		
16	18¾	14	11	8¾	7	5¾	4¾	4	
18		17¾	14	11	8¾	7¼	6	5	4
20	...		17	13½	10¾	9	7¼	6	5¼
22	...	...		16½	13	10¾	8¾	7½	6¼
24	...	...		19½	15½	12¾	10½	8¾	7½
26	...	...	...		18¼	15	12¼	10¼	8½
28	...	...	...	...		17¼	14¼	11¾	10
	Depth, 19 in.	Depth, 20 in.	Depth, 21 in.						
	Breadth.	Breadth.	Breadth.						
30	9¾	8½	7¼	...	...	19¾	16¼	13½	11½
32	11	9½	8¼	...	...		18½	15½	13
34	12½	10¾	9½	...	...	...		17½	14¾
36	14	12	10½	...	...	...	...	19½	16½

TREDGOLD'S RULES FOR SCANTLING OF FLOOR TIMBERS.—

L = Length in feet. B = Breadth in inches. D = Depth in inches.

Bridging or Common Joists (12 inches from centre to centre).—

$$D = \sqrt[3]{\frac{L^2}{B}} \times 2\cdot2 \text{ for fir, or} \times 2\cdot3 \text{ for oak.}$$

Trimmers and Trimming Joists (see p. 132).

Binding Joists (6 feet apart).

$$D = \sqrt[3]{\frac{L^2}{B}} \times 3\cdot42 \text{ for fir, or} \times 3\cdot53 \text{ for oak.}$$

$$B = \frac{L^2}{D^3} \times 40 \text{ for fir, or} \times 44 \text{ for oak.}$$

Girders.—$D = \sqrt[3]{\frac{L^2}{B}} \times 4\cdot2$ for fir, or $\times 4\cdot34$ for oak.

$$B = \frac{L^2}{D^3} \times 74 \text{ for fir, or} \times 82 \text{ for oak.}$$

Ceiling Joists (12 inches from centre to centre).—

$$D = \frac{L}{\sqrt[3]{B}} \times 0\cdot64 \text{ for fir, or} \times 0\cdot67 \text{ for oak.}$$

When ceiling joists are of the usual thickness of 2 inches, half the length of bearing in feet will give the depth in inches.

Chapter VII.

CARPENTRY—(*Continued*).

TIMBER BEAMS, CURVED RIBS, AND TRUSSED TIMBER GIRDERS.

Built-up Beams.[1]—Timber girders are substantial beams supported or fixed at the ends, and generally destined to carry a load throughout the whole or part of their length.

In Part IV. will be shown the method of ascertaining the form and dimensions for plain timber beams, intended to support loads concentrated at different points or uniformly distributed.

It will be found that, for spans exceeding 20 feet, the girders to carry even moderate loads will require considerable sectional dimensions.

It is most difficult and expensive to get sound timber of large scantling, and moreover there is a practical limit to the sizes of timber procurable, beyond which it cannot be obtained at all.

These difficulties have led to various expedients :—

1. For building up large beams out of pieces of smaller scantling.

2. For strengthening beams by the addition of iron, arranged with the view of relieving the timber of part of the stress which comes upon it.

Built-up Beams.—When beams are required of such a size that timber large enough for them cannot be procured without danger of defects, they may be built up of smaller pieces, arranged as shown in Figs. 318, 319, which are taken from Tredgold's *Carpentry*.

JOGGLED OR KEYED BEAM.—Fig. 318 shows a simple form of built beam,

Fig. 318. *Keyed Beam.*

consisting merely of two pieces of timber bolted together, and prevented from sliding by hard wood keys, having their grain at right angles to that of the timber.

[1] Built-up beams and girders trussed within their depth are now not much used in this country—having been superseded by rolled steel beams and riveted girders—but they may be useful in new countries where steel girders cannot be obtained.

The upper portion may be cut into two, and the halves forced outward by a king bolt with bevelled sides, as shown in Fig. 319.

It is better, however, that no bolt or key should be placed in the centre, as at that point the transverse stress is in most cases the greatest.

Rule.—The depths of all the keys added together should be more than $1\frac{1}{3}$ of the whole depth of the beam, and the breadth of each about twice the depth.—TREDGOLD.

INDENTED BEAMS.—The sliding may be prevented by indentations, as shown in Fig. 319, instead of keys. The upper layer of the beam is sometimes made in two pieces, a vertical wedge-shaped king bolt being inserted at the centre, with its narrow end downwards, so that by screwing up the nut the parts of the upper layer are forced outwards and the joints tightened.

Rule.—The depth of all the indents added together should equal $\frac{2}{3}$ depth of the beam.—TREDGOLD.

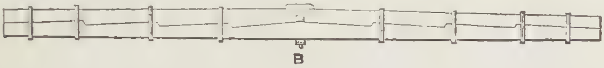


Fig. 319. *Indented Beam.*

When straps are used instead of bolts, the beam should be slightly tapered towards the ends to facilitate driving them on.

When a beam is built up in two layers, the upper may with advantage be of hard wood, as it will be compressed when a transverse stress comes upon the beam. The lower layer should be of tough straight-grained timber, to resist the tension to which it will be subjected.

For very long beams it may be necessary to have two or three pieces in the length as well as in the depth. These should, in the lower layer, be scarfed together as described in Chap. V.; in the upper layer they may simply butt against one another.

These elaborate methods of building up beams of considerable length and scantling are given in old books on carpentry, but are now practically superseded by the use of steel or iron girders.

Curved Ribs are sometimes obtained from naturally curved timber sometimes artificially bent (see Part III.), or sometimes built up as follows.

BUILT RIBS are best constructed on a method invented by Philibert de l'Orme (see Figs. 320, 321).

Several layers of plank on edge are placed together so as to break joint, and are united by bolts or wedges passing through them.

If a curved rib be required, the corners *a b c d e* are rounded off.

Fig. 320. *Elevation.*

Fig. 321. *Plan.*
Built Rib.

A built rib of this sort properly constructed is nearly as strong as a solid rib of the same depth, and of a breadth less by the thickness of *one layer.*—RANKINE.

LAMINATED RIBS are composed of layers of planks placed flatwise, breaking joint and bolted together, as in Fig. 322. They are easily made.

Fig. 322. *Laminated Rib.*

Their strength, compared to that of solid ribs, is as 1 to the number of layers of which they are composed.—Rankine.

Built and laminated ribs are used in some forms of roofs, which, however, do not fall within the limits of this volume.

STRENGTHENING TIMBER BEAMS.

The strength of timber beams or girders varies directly in proportion to their breadth and to the square of their depth, and inversely as their length (see Part IV.)

It is, however, often necessary to strengthen a girder without adding to its dimensions, as, for instance, in a floor where too deep a girder would extend below the ceiling or lessen the height of the room below.

In such a case all extraneous aid afforded to the girder by means of trussing or otherwise, must be kept very nearly or quite within the limits of the wooden beam.

Flitch Beams.—A beam may be improved by cutting it down the middle, reversing one of the halves (called "flitches"), end for end, and bolting them together with the sawn sides outwards, small slips of wood being introduced between the flitches to keep them an inch or two apart, so as to allow a free circulation of air between them.

This arrangement causes the timber to season more quickly and thoroughly, as the pieces are smaller; it also renders the heart of the wood visible, so that any decay can be detected; moreover, the reversal of the flitches, end for end, makes the beam of equal strength throughout, which is very seldom the case in a long balk, as the top of a tree is generally weaker than the butt.

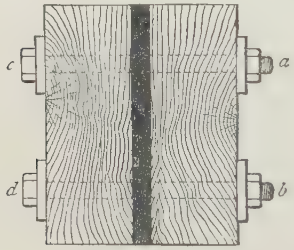


Fig. 323.

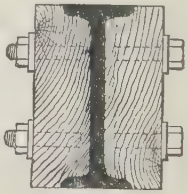


Fig. 324.

Iron Flitches.[1]—A beam thus cut down the middle is frequently strengthened by placing an iron plate or "flitch" between the

[1] Or Sandwich Beams.

halves, and bolting the whole together, as shown in the section Fig. 323.

The bolts are placed in the length of the beam so that the upper ones are over the centres of the intervals below the lower ones.

A writer in the *Building News* has shown that, when the depth and length of the iron plate is the same as that of the flitches, its thickness, in order that it may be effective, should be at least $\frac{1}{8}$ of that of each flitch.

A rolled girder, as shown in Fig. 324, is, in some cases, used instead of the iron plate.

Trussed Beams.—*Beams trussed within their own depth.*—Beams have frequently been strengthened by a "truss" constructed within their own depth.

Such a truss may be formed by splitting a balk longitudinally down the centre, and inserting between the flitches two cast-iron struts, *s s*. Along the bottom of the beam is a tension-plate, supported by a king bolt in the centre, and by a somewhat similar bolt, *b*, at each end, after which the "flitches" are bolted together as shown in Fig. 326.

Fig. 325. *Section through Centre.*

Fig. 326[1] *Plan.*

Fig. 325 is a section through the centre of the iron truss, showing the farther flitch and bolt-holes in elevation.

The ends of the struts are secured as follows:—

The bolt *b* passes through the beam and secures the ends of the tension plates by means of the cog *c*; the lower part of the bolt is shaped so as to form an abutment for the struts *s*, and it is supported in the centre by the transverse bolt seen in section at *t*.

The truss adds to the strength of the girder so long as the bolts are screwed up, and all the parts are bearing accurately.

A similar truss may be formed as in Fig. 327, with two queen bolts instead of the king bolt.

Fig. 327.

The struts are sometimes formed of oak or other hard wood instead of iron.

Beams may be trussed with tension rods as shown in Fig. 328. The balk is split longitudinally into two, as before described, and the truss inserted between the flitches.

[1] Modified from Newland's *Carpenter's and Joiner's Assistant.*

Fig. 328 is an elevation of the exterior of such a beam. The ends of the

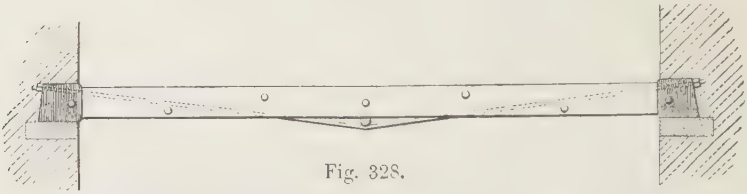


Fig. 328.

tension rod pass through cast-iron boxes capping the ends of the beam, and are there secured by nuts.

The cast-iron boxes are useful to protect the ends of the beam, especially when the latter are imbedded in masonry, but they are often dispensed with; the upper corners of the beam being cut off at right angles to the direction of the tension rod, and the nuts screwed up against a washer or plate, as in Fig. 329.

The centre of the rod bears against a cast-iron bar attached to the under side of the beam.

It will be seen that a shrinkage in the depth of this beam frees it from the tension rod, which becomes slack and plays no part whatever; it can, however, be again brought into action by screwing up the nuts at its ends.

In the meantime, however, the whole strain has come upon the timber, unassisted by the iron work.

Fig. 329.

The same description of truss may be used with two bearing points for the tension rod, as shown in Fig. 329.

Sir W. Fairbairn experimented upon beams with 4 feet 6 inches bearing, and 4 inches deep trussed as shown in Fig. 328, and found that the trussed beam was $\frac{1}{5}$ stronger than a simple beam of the same dimensions.

Figs. 328, 329 show the position of the tension rods as they are usually placed, but Sir W. Fairbairn states[1] that "in the construction of truss beams, whether of wood or iron, the truss rod should never be carried to a greater height than the horizontal line passing through the centre of the beam."

Girders trussed within their own depth are objected to because the inevitable shrinkage of the timber slackens the iron work, and throws the whole strain upon the timber; which may therefore become crippled before the truss can be tightened up and the iron brought again into play.

Moreover, from the nature of the construction, especially when the girder is "cambered" in order to gain stiffness, the ends are subjected to great compression, which acting upon a small area is apt to crush the fibres.

This strain may be considerably reduced where there is sufficient depth by increasing the angle of inclination of the tension rods, as in girders of the form shown in Fig. 330, which are not so open to this objection.

The great difference in the nature of the materials composing the truss renders it almost impossible that the parts should act together in performing the work required of them.

Theoretically, they should be so adjusted that the members in compression are on the point of being crushed, at the exact moment that the parts in tension are about to tear asunder. To arrange this would require great skill and nicety in proportioning and fitting the parts; and, even if it were

[1] P. 350. Application of Iron to Buildings.

accomplished, slight changes caused by exposure to the atmosphere would soon utterly destroy the adjustment.

For these reasons beams trussed within their own depth are in some disrepute and are seldom used.

Beam with deep Trussing.—Where circumstances do not limit the depth of the trussing, it may be used with great advantage.

Fig. 330 shows a form of truss frequently adopted for purlins

Fig. 330. *Beam with deep Trussing for Dead Load.*

of great length (see Chap. XI.), for beams of long bearing used in gantries,[1] and for travellers. This form of truss is, however, suitable only for a purlin or similar bearer carrying a uniform stationary load throughout its length; when it has to carry a moving weight it should be strengthened by cross braces as in Fig. 333.

The extremities of the beam are enclosed in cast-iron boxes. These receive the ends of the tension rods, which pass through them and are secured by nuts.

The bearing surface of the nut should be at right angles to the direction of the tension rod; this may be effected by cutting off the ends of the beam obliquely at right angles to the tension rod, as in Fig. 331, and shaping the box accordingly—when the end of the beam and box is vertical a patch may be cast upon the box, or a splayed washer introduced so that the bearing may be at right angles to the rod.

The stays or struts (*s s*) are generally of cast iron secured to the under side of the beam; in very rough work short posts of wood are used instead.

The tension rod may pass through the centre of the beam as shown, or a rod may be used on each side.

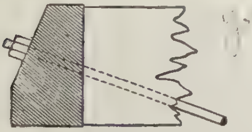


Fig. 331.

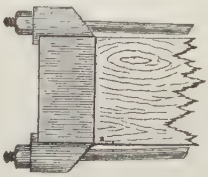


Fig. 332.

Trussed Ends of Beams.

In this case the cast-iron boxes have an ear on each side to receive the bars as shown in Fig. 332.

[1] See Part II.

For smaller spans only one stay in the centre may be used instead of two as shown in Figs. 330, 333.

The truss is sometimes strengthened by diagonal ties, AD, BC, Fig. 333, which are necessary when the points A B are unequally loaded.

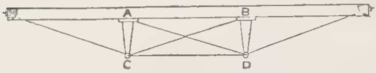


Fig. 333. *Trussed Beam for Moving Load.*

This form (Fig. 333) is therefore particularly adapted for the bearers of travellers, and others required to carry a moving load.

Chapter VIII.

CARPENTRY—(*Continued*).

PARTITIONS.

PARTITIONS are used to divide rooms from one another, instead of walls, to save space and expense, and they are desirable in upper stories where there are no brick or masonry walls below the divisions required between the rooms.

Quartered Partitions consist of framings filled in with light scantlings or "*quarterings*," upon the sides of which laths are nailed and plastered.

These may be "*framed*" or "*common*,"—the former being trussed so as to carry their own weight between the walls as abutments, the latter merely resting upon a dwarf wall when intended for the ground floor—and in other cases upon walls, floors, or rolled iron joists or whatever may be immediately below them.

Brick-nogged Partitions (see p. 157) have the intervals between the quarterings filled in with brickwork, upon which the plastering is laid.

General Remarks (chiefly from Tredgold's *Carpentry*).—Partitions containing timber should not be used on the floor next to the ground, as the wood is affected by the damp and decays. Stone or brick walls are therefore preferable in such positions.

A quartered partition sometimes rests on the cross and party wall of the ground-floor. This is not a good arrangement, as the partition becomes cracked in consequence of its being unable to settle together with the main walls to which it is fixed.

Nor should the weight of the partition be allowed to rest on the floor below it, as it bears heavily upon the joists, cracks the ceilings below, and also settles and tears away from the ceiling above it.

A better arrangement is to suspend the partition from the floor or roof above; this prevents the cracking of the cornice above the partition.

Of course, if the weight of the partition be thrown upon either of the floors or the roof, these latter must be strengthened accordingly.

By far the best plan, however, is to make the partition self-supporting, depending only on the main walls carrying its ends, and forming, in fact, a very deep truss.

If the trussed partition be supported by two walls of very unequal height they may settle unequally, and, if so, will cause it to crack. If the walls are of equal height and well founded they will settle equally, and the partition moving with them will sustain no injury.

The framing of the truss should be so arranged as to throw the weight upon the points of support in the walls at the end of the truss.

Partitions should be made of very well-seasoned timber, and the joints carefully fitted. The whole should be allowed to stand for some time before being lathed, so that the timber may take its bearings and twisted timbers may be put right before plastering.

Common Partitions.—Tredgold states that when a partition rests on a floor or is otherwise supported throughout its length it is better without braces, the quarterings being simply steadied by horizontal pieces nailed between or across them.

Fig. 334 is an elevation of a common partition. Its sill (*s s*)

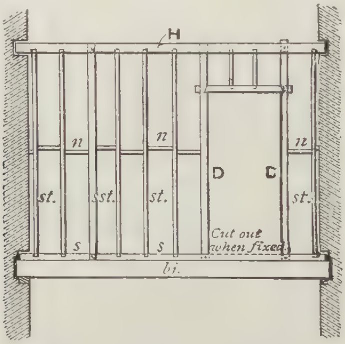


Fig. 334. *Common Partition.*

rests upon the floor below, two joists being laid close side by side

and bolted together to support it. The head H enters the walls at its ends, but they should not rest upon the wall.

The filling-in pieces, *studs, quarterings,* or *quarters* (*st*), should be of light scantling just so thick (about 2 inches) that the laths can be nailed to them. They are stub-tenoned to the top and bottom plates, and stiffened by short struts (*n n*) called *nogging pieces,* or by continuous rails (*h h*), as in Fig. 335, notched on to the uprights and nailed to them.

The nogging pieces should be fixed as shown, alternately, at different levels, so that their ends may be got at for nailing, and should not come up flush with the face of the stud on either side or they will interfere with the key for the plastering.

The studs should be placed at such a distance apart as will suit the lengths of the laths. These are generally 3 or 4 feet long, and the studs may be at 12 inches central intervals, so that the ends of the laths may fall upon every third or every fourth stud.

The studs D on each side of the door are called the *door-studs, principal posts, uprights,* or *double quarterings.* They are tenoned through the head and sill, and so are the *stiffening studs* (*s s t*), one of which is shown in the figure.

In trussed partitions the studs should be about ½ inch on each side wider than the timbers of the truss, the nogging pieces, and any other timbers with wide surfaces. Narrow half-inch pieces are nailed upon these surfaces to receive the laths, so that the key for the plastering may not be interrupted, and that room may be left for the shape of the truss when these are away.

Tredgold recommends that when extra strong and sound-proof partitions are required, the studs should not be filled in between the framing but nailed on the outside as battens, and then plastered.

When the partition rests on the floor below, [illegible] project inconveniently above the floor in the [illegible]. That portion of the sill is therefore cut out after the partition is fixed.

Framed Partitions.—Framed Partition without Doorways —This may be formed like an ordinary king-post truss, filled in as described below.

Framed Partition with Ordinary Doorway in the Centre. —A truss of queen-post form may be used, as in Fig. 335, which is taken from Tredgold's *Carpentry.*

The *braces* (*bb*) correspond to the principal rafters, and Tredgold recommends that they should be inclined at an angle of about 40° with the sill (SS).

The doorhead fulfils the part of the straining beam,[1] while the bottom plate or "*sill*"[2] (SS) corresponds to the tie beam, and may pass between the joists under the floor boards.

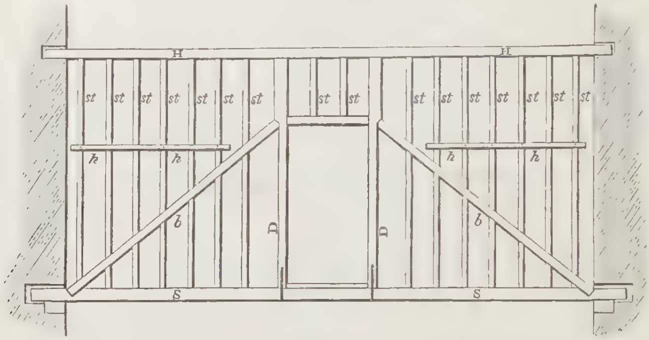


Fig. 335. *Framed Partition with Doorway in centre.*

FRAMED PARTITION WITH WIDE DOORWAY IN CENTRE.—Fig. 336 shows a partition with queen-post trusses, and having in the centre a wide doorway to receive folding-doors.

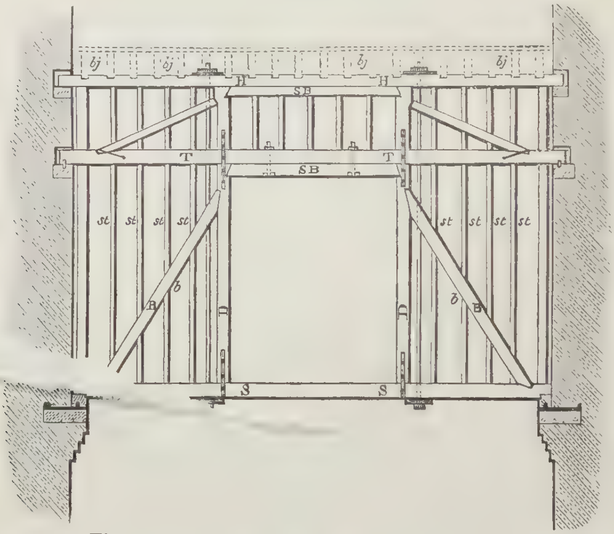


Fig. 336. *Framed Partition with wide Doorway.*

It will be seen that the trusses carry the whole weight of the partition, and transmit it to convenient points in the walls, where stone templates are provided to support the ends of the head or top plate (H), the *intertie* (T), and the sill (S).

[1] See Chap. XI. [2] Sc. *Sole*, or sometimes *Bottom Runner*.

The framing is further strengthened by the bolts on each side of the doorposts.

This is a very strong partition, and adapted for bearing, if necessary, the weight of the floor above it, which latter is shown in dotted lines.

A partition of this form is said to be "one-fourth trussed," signifying that the upper truss occupies that proportion of the whole depth.

FRAMED PARTITION WITH SIDE DOORS.—The partition in Fig. 337[1] is sustained by the king-post truss over the doorways, from which hangs the lower portion of the framing.

The floor below is dotted in order to show the pieces (x) which are framed in between the joists to form a support to the feet of the doorposts.

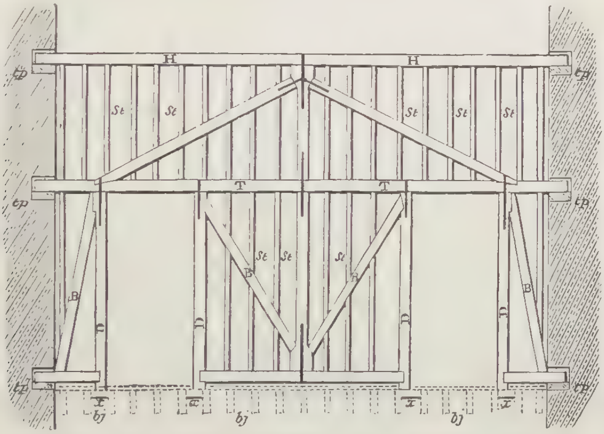


Fig. 337. *Framed Partition with Doorways at sides.*

Details.—Figs. 338, 339 give enlarged illustrations of some of the joints of the partition shown in Fig. 337.

Partition extending through more than one Story.—In some cases partitions are carried up one above the other through two or three stories. Such partitions may be so arranged as to assist one another. Fig. 340 gives an outline of a partition extending through two stories, in which the door studs of the upper partition are supported by the queen posts of the truss of the one below.

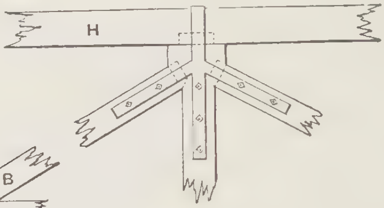
In this particular example no straps are used, the tightening up of the truss being effected by the bolts shown in dotted lines.

Since the introduction of constructional steel-work, metallic lathing, and reinforced concrete, the use of elaborate trussing for partitions has practically become to a great extent obsolete.

[1] Modified from an example in Newland's *Carpenter's and Joiner's Assistant.*

The forms of partition devised to suit particular requirements are endless, but the arrangements shown, or modifications of them, will be found to be adapted for most ordinary cases.

Fig. 338.



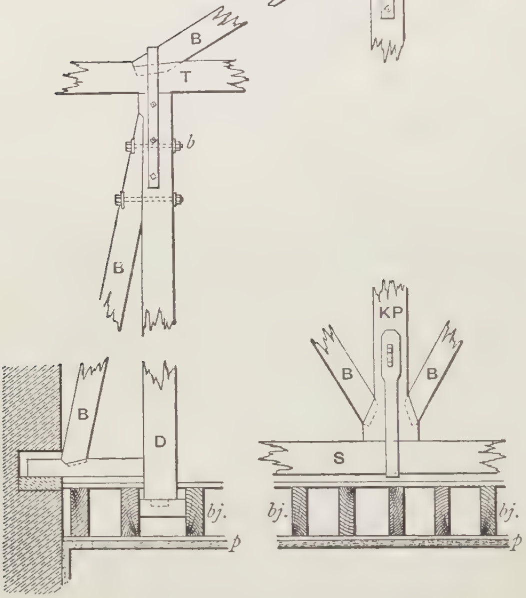


Fig. 339. *Details of Partition.*

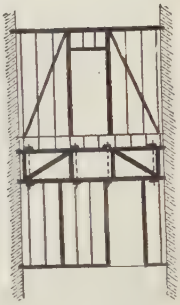


Fig. 340. *Partition through two Floors.*

Wrought-iron tie rods, also cast-iron sockets and shoes, are often used (for the same purposes as in roofs) in partitions of large size, or those which have to bear a great weight.

Iron straps are also used as in roofs, but in partitions they are often unnecessary and have the great disadvantage of interfering with the key of the plastering, unless trouble is taken as described (p. 153) to prevent this.

Weights and Scantlings of Partitions.

	Pounds per square.
The weight of a square of partitioning may be taken at from	1480 to 2000.
The weight of a square of single-joisted flooring, without counter-flooring	1260 to 2000.
The weight of a square of framed flooring, with counter-flooring	2500 to 4000.

Scantlings for the principal timbers of a partition bearing its own weight *only*—

4 inches by 3	inches for bearing not exceeding			20 feet.
5 ,, by $3\frac{1}{2}$	,,	,,	,,	30 ,,
6 ,, by 4	,,	,,	,,	40 ,,

If the partition has to sustain the weight of a floor or roof, the sizes of the timbers must be increased to meet the additional strain that will come upon them.

The filling-in pieces should be just thick enough to nail laths to, about 2 inches (see p. 153).

Any timbers more than 3 inches wide on the face, to which the laths are nailed, should have the corners taken off so as not to interrupt the key for the plaster.—*Tredgold.*

Brick-nogged Partitions are screens of timber filled in with brickwork ("*brick nogging*") about $4\frac{1}{2}$ inches thick.

In very common work, or when there is not room for a thicker partition, the brick nogging is of brick on edge, and therefore only 3 inches thick.

In a brick-nogged partition the quarterings should be at a distance apart equal to some multiple of the length of the bricks used, so that an exact number of bricks may fit in between them without the expense of cutting.

Horizontal "*nogging pieces*" about 1 inch to 3 inches thick should be fitted in between them in every third or fourth course of the brickwork. They are frequently placed at much deeper intervals.

Since the introduction of Portland cement, half-brick walls have greatly superseded brick-nogged partitions wherever partitions occur one above the other.

Metallic Lathing.—Recent developments in the application of steel to building purposes may be found in various kinds of metallic lathing in the market, which are used in place of wood laths, either in the form of wire netting or thin sheet steel shaped to various forms to give a key to the plaster in which the lathing is embedded. This form of construction is applicable to partitions, floors, ceilings, and the protection of columns and girders from fire.

Chapter IX.

CARPENTRY—(*Continued*).

CENTRES.

CENTRES are temporary structures of wood, with curved upper surfaces upon which arches are built, and left until they are consolidated and have taken their bearing, after which the centres are removed.

For large arches, such as those of bridges, very elaborate centres are required, with special arrangements for easing and striking them gradually; but in ordinary buildings the centres are very simple; the arches for which they are required being generally of small span and common construction.

Centres for very small and narrow arches may consist simply of a piece of wood cut to the curve of the soffit of the arch, and supported under it by props. Such centres are called "*turning pieces.*"

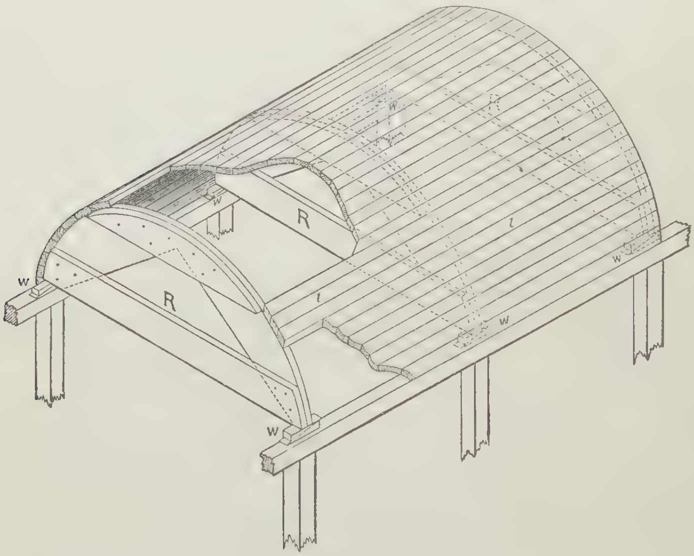


Fig. 341.

For longer arches, such as those of tunnels, sewers etc., the

centre is composed of several curved frames or "*ribs*," RRR, supporting narrow battens nailed across them, and called "*laggings*,"[1] *lll*, Figs. 341, 342.

For stone arches,[2] or very rough brick arches, the *laggings* may be of narrow battens placed an inch or more apart; but for superior brick arches they must be of close boarding smoothed off with an adze, so that the courses may be lined out on the surface.

The feet of the props rest either upon the ground or upon the footings of the walls. When the walls are very high, corbels may be introduced to support the props or struts.

Laggings should be fixed with as few nails as possible, in order to save trouble in removing the centering when done with.

When the arches exceed 3 or 4 feet span the centres are made up of pieces nailed together, as in Fig. 341.

As the span increases the form of the ribs becomes more complicated; up to spans of 20 feet, however, ribs like that shown in Fig. 342, will do very well.

They are placed from 2 to 6 feet apart, the interval being regulated by the thickness of the lagging and weight of arch.

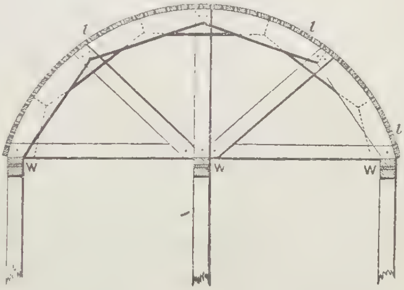


Fig. 342.

More elaborate centres are never required in ordinary buildings, and it will be unnecessary further to advert to them.

Easing.—In building all but the very smallest arches arrangements should be made for *easing* the centre, so as gradually to deprive the arch of its support.

This is done by means of pairs of greased wedges introduced between the heads of the props and the ribs (see WW, Figs. 341, 342).

After the arch has been turned, and the haunches filled in, the points of these wedges are lightly struck so as to drive them outwards from the rib under which they are placed, thus lowering the centre a very little; this causes the whole of the arch to

[1] Sc. *Cleading.*

[2] Frequently in arches of large stones there are only one or two pieces of lagging under each stone.

settle slightly and uniformly and to take its bearing, the mortar being compressed in the joints.

The arch is then left until the mortar has set, after which the centres are removed altogether.

Some engineers defer the easing of the centres for a day or two after the arch is built. When an arch is built of very soft stone or bricks it is better not to ease the centering, as the pressure on the edges of the voussoirs is apt to chip them.

In centres for very important stone arches, wedges or screws are frequently placed under *each* "lagging" separately, so that the work may be eased, course by course, and the support replaced if the settlement is too rapid.

Arrangements are sometimes adopted for easing all the wedges at the same time, so that the whole arch may settle uniformly.

Scantlings.—These depend in practice a good deal on the rough stuff available.

For a brick arch 2′ 3″ thick and 20′ span, a centre such as that in Fig. 342 would have the king-post, struts, and portions of ribs, cut out of 2″ stuff. The laggings would be of $1\frac{1}{2}$″ stuff for ribs 3′ apart or 2″ stuff for ribs 4′ or 5′ apart.

Centering for Concrete Arches.—The laggings should be only 3 or 4 inches wide, laid close, the joints being run in with whiting and plaster of Paris. The centering should not be disturbed for a fortnight, or until the concrete has set.[1]

[1] R. E. *Aide Memoire.*

CHAPTER X.

CARPENTRY—(*Continued*).

TIMBER ROOFS.

THE roof of a building is intended to cover it, and to keep out the weather.

There are many different ways of arranging the timbers of a roof, which vary according to the span, the requirements of the building, the climate, and the nature and weight of the covering to be used.

This course extends only to a consideration of one or two of the most ordinary forms for roofs for small span, and terminates with a description of the "King-post Roof."

It will be well to trace the gradual development of the King-post Roof before describing it in detail.

N.B.—In all the figures illustrating this section, the parts are marked with the distinctive letters mentioned below.

Battens	*b*	Parapet Wall	PW
Binders	*Bi*	Pole Plate	*pp*
Blocking Course	BC	Purlin	P
Boarding	B	Rafters, Principal	PR
Ceiling Joists	*cj*	,, Common	CR
Cleats	*cl*	Ridge	*r*
Collar Beam	CT	Slates	*s*
Cornice	C	Soffit	*fs*
Corbel	*c*	Struts	S
Fascia	*f*	Templates (wall)	*wt*
Gutter	*g*	Tie Beam	T
Gutter-bearer	*gb*	Tilting Fillet	*tf*
Gutter-plate	*gp*	,, Batten	*tb*
King Bolt	KB	Truss, Principal	TP
,, Post	KP	Wall Plates	*wp*
,, Tie	KT		

Flat Roof.—The simplest covering for a house would at first seem to be beams laid from wall to wall, forming a flat roof. This

is in use in some countries, but it has many practical disadvantages.

The rain and snow are not thrown off, and will leak through the slightest opening.

In consequence of this, the material to cover a flat roof must be one (such as lead or copper) in which there are no open joints.

Such roofs must be restricted to small spans; if not they will require very heavy timbers, or expensive girders.[1]

Pitch of Roofs.[1]—In order to throw off the rain and snow, it is necessary to tilt up the sides of the roof, giving them a slope as shown in Figs. 343, 345, etc.

The inclination of the sides of a roof to the horizontal plane is called its "*pitch*," and is described either by the number of degrees contained in the angle of inclination to the horizon, or by the proportion which the height, from the springing line to the apex, called the "*rise*," bears to the span.

Thus, a roof whose sides slope at $26\frac{1}{2}°$ to the horizon, has a rise equal to $\frac{1}{4}$ of the span, and is called a roof of $\frac{1}{4}$ or $26\frac{1}{2}°$ pitch. The best angle for the slope of the sides of a roof depends upon the material to be used to cover it, the climate, etc. (see "Roof Coverings," Chap. XII.)

This course includes the consideration of slated roofs only, and the pitch found by experience to be the best for slates of different sizes is given at page 216.

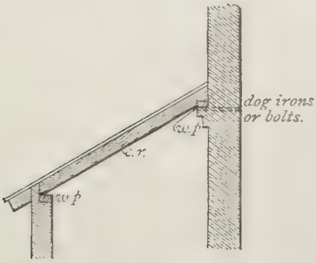


Fig. 343. *Lean-to Roof.*

A Lean-to Roof[2] has only one side or slope which is fixed between two walls one higher than the other. Fig. 343 is a section of such a roof. The rafters (*cr*) are nailed to the wall plates (*wp*), the higher of which is well secured to the wall by bolts, so that the stress upon the rafter may not pull it out.

A Couple Roof[3] is one formed by the meeting of two beams or rafters (R R) fixed at an inclination. Their feet are nailed and frequently also notched upon a wall plate imbedded on the top

[1] Latterly, in densely populated districts where space is much required, flat roofs have been largely used, but they are generally constructed of iron, concrete, and asphalt, and do not come within the scope of this chapter.

[2] Sc. *Too-fall.*

[3] Sc. sometimes spelt *Cupple.*

of the wall, and their heads meet upon a ridge board (r) to which they are secured by nails.

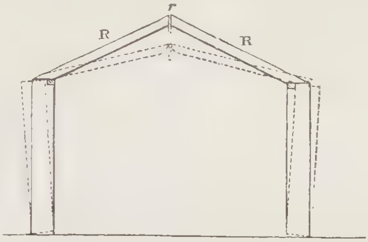


Fig. 344. *Couple Roof.*

In such a roof there is nothing to prevent the rafters from spreading out and thrusting over the walls as shown in dotted lines.

This form of roof may, however, be adopted for spans up to 18 feet.

SCANTLINGS FOR SINGLE SPAN OR COUPLE ROOFS[1] of Baltic Fir Timber, with rise $\frac{1}{4}$ span; slated with countess slates on boarding.

Span from centre to centre of Wall Plates.	Rafters, R.	Ridge Board, r.	* Ceiling Joists, (if used).	Remarks.
8 feet.	3 by 2	7 by $1\frac{1}{2}$	4 by 2	* From wall to wall 2″ wide by $\frac{1}{2}$″ deep per foot run of span.
10 ,,	$3\frac{1}{2}$ by 2	7 by $1\frac{1}{2}$	5 by 2	
12 ,,	4 by 2	7 by $1\frac{1}{2}$	6 by 2	
14 ,,	$4\frac{1}{2}$ by 2	7 by $1\frac{1}{2}$	7 by 2	With these spans 14″ brick walls built in ordinary lime mortar would be too weak, and must be strengthened or relieved of the thrust of the roof.
16 ,,	5 by 2	8 by $1\frac{1}{2}$	8 by 2	
18 ,,	$5\frac{1}{2}$ by 2	8 by $1\frac{1}{2}$	9 by 2	

Couple-close Roof.—To remedy the defect above mentioned, a tie (T T, Fig. 345) is added, which, by holding in the feet of the rafters, prevents them from spreading and thrusting out the walls. The strain on the tie, caused by the tendency of the rafters to settle and spread out can easily be calculated, and it will be found that a comparatively slight rod of iron will be sufficient to hold the feet of the rafters together.

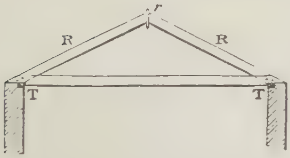


Fig. 345. *Couple-close Roof.*

In timber roofs, however, a wooden beam is generally used for the tie, and it is frequently required to act as a ceiling joist, or to carry ceiling joists, for which an iron rod would not be suitable.

These wooden "*tie beams,*" especially when loaded, have a tendency to "sag," or droop in the middle, and to draw the walls inwards.

Collar-beam Roofs.—In buildings where considerable height is

[1] From Wray's *Application of Theory to the Practice of Construction.*

required internally, or in those with low walls where the tie beam would be in the way of the occupants; it is replaced by a "collar

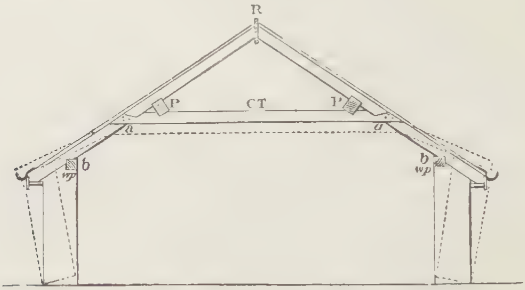


Fig. 346. *Collar-beam Roof.*

beam"[1] (CT) placed higher up, as shown, so as to give the required space below.

This is a bad construction; the lower parts (a b) of the rafters are liable to bend if the walls are not competent to take the thrust, and as they are not tied in at the feet they thrust on to the walls, tending to force them out, as shown in dotted lines.

This tendency is sometimes aggravated by using the supported rafters as *Principals*,[2] placing them 8 to 10 feet apart, and adding purlins (P P) resting upon the collar as shown; these carry light intermediate rafters, the weight of which, with their load, increases the evils already pointed out.

The collar is generally about halfway up the rafters, and is intended to act as a strut and support them in the middle, but when the walls give way the collar becomes a tie, and tends to assist the bending of the rafters.[3]

This construction is therefore objectionable, except for small buildings not exceeding 18 feet span, when the distance a b is small, the rafters stout enough to prevent bending, and the walls thick in proportion to the span. When a ceiling is applied to a collar-beam roof it follows the line b a, a b. The collar beam is sometimes supported by an iron rod hanging from the ridge (R).

There are many forms of roof in which the tie beam is dispensed with for the sake of appearance, or to gain height. Several of the Gothic roofs are of this class, but the consideration of such is beyond the scope of these notes.

[1] Sometimes called *Top beam, Wind beam.* Sc. *Baulk.* [2] See p. 167.

[3] The weakness of the lower part of the rafters is sometimes remedied by strapping pieces under them from a to b (see Fig. 346). These pieces may be continued so as to fill the angle at a, and support the collar beam.

If a tie beam at the level of the springing be added to a collar-beam roof, as shown by the dotted line in Fig. 355, the collar becomes permanently a strut, and a very good roof is formed.

SCANTLINGS for COLLAR-BEAM ROOFS. Pitch up to 30°.
If 45°, add 1″ to depth of rafters.

SPAN.	RAFTERS. One foot apart, or centre to centre if very exposed site. Countess slates on $\frac{3}{4}$″ boards. Rafters not to be cut into in fixing collars.				COLLARS.	
	Thrust taken by walls or ties. Compression collars $\frac{1}{2}$ way up.		Walls incapable of taking thrust. Tension collars $\frac{1}{4}$ way up.*		From $\frac{1}{4}$ to $\frac{1}{2}$ way up.	At any height.
	No ceiling.	Ceiled to collars.	No ceiling.	Ceiled to collars.	No ceiling.	Ceiled to collars.
feet.	inches.	inches.	inches.	inches.	inches.	
8	$1\frac{1}{2} \times 2\frac{1}{2}$	$1\frac{3}{4} \times 3$	$2\frac{1}{4} \times 3\frac{1}{4}$	$2\frac{1}{4} \times 3\frac{3}{4}$	$1\frac{3}{4} \times 2\frac{1}{2}$	2″ wide × $\frac{1}{2}$″ more than $\frac{1}{2}$″ per ft. of clear length of underside of collar.
10	$1\frac{3}{4} \times 2\frac{1}{2}$	$1\frac{3}{4} \times 3$	$2\frac{1}{4} \times 4$	$2\frac{1}{4} \times 4\frac{1}{2}$	$2 \times 2\frac{1}{2}$	
12	$1\frac{3}{4} \times 2\frac{3}{4}$	$1\frac{3}{4} \times 3\frac{1}{4}$	$2\frac{1}{4} \times 4\frac{1}{2}$	$2\frac{1}{4} \times 5$	$2 \times 2\frac{3}{4}$	
14	$1\frac{3}{4} \times 3$	$1\frac{3}{4} \times 3\frac{1}{2}$	$2\frac{1}{2} \times 5$	$2\frac{1}{2} \times 5\frac{1}{2}$	2×3	
16	$2 \times 3\frac{1}{4}$	$2 \times 3\frac{3}{4}$	$2\frac{1}{2} \times 5\frac{1}{2}$	$2\frac{1}{2} \times 6$	$2 \times 3\frac{1}{2}$	
18	$2 \times 3\frac{3}{4}$	$2 \times 4\frac{1}{4}$	$2\frac{1}{2} \times 6$	$2\frac{1}{2} \times 9\frac{1}{2}$	2×4	

* If the collar is required half-way up, about $\frac{1}{4}$″ must be added to both breadth and depth of rafters, and $\frac{3}{4}$″ to depth of collars, but with unstable walls, ties are far cheaper, and may be at long intervals if sufficient width is given to the wall plates to enable them to take the thrust between the ties.

Thickness of Walls to resist Thrust of Roof.

The following *solid* walls are strong enough, when built in Lias lime mortar 1 to 2, to resist the thrust of roof; allowance must be made for door and window openings. Height to be taken from level of the floor below roof.

Stone Wall.	Brick Walls.
16″ thick not over 15′ high.	Span of roof 10′ { 9″ thick, not over 7′ high. 14″ ,, ,, 14′ ,, Span of roof 18′ { 9″ ,, ,, 5′ ,, 14″ ,, ,, 10′ ,,

When the walls are not capable of resisting the thrust of the roof place the collar low down; but if the collar is required half-way up, the scantlings must be increased as follows:—

Rafters, add quarter inch to both breadth and depth; *Collar*, add three-quarter inch to depth, but it would be better to use the scantlings for walls capable of taking the thrust, and make some arrangement to prevent the walls from spreading, such as tying the wall plates together at intervals.[1]

King-rod Roof without Struts.—To prevent the tie beam of a

[1] From Wray's *Application of Theory to the Practice of Construction.*

couple-close roof, when supporting a ceiling, from sagging or bending with the weight of the ceiling,[1] it may be supported in the centre by an iron king rod (KR), suspended from the ridge *r*.

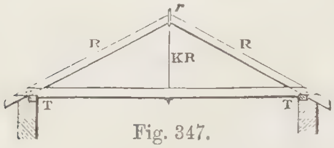


Fig. 347.
King-rod Roof (without Struts).

For spans of from 14 to 18 feet a collar may be introduced half-way up the rafters to stiffen them.

We have now arrived at a form of roof in which the feet of the rafters cannot spread outwards, and whose tie beam is prevented from sagging or drooping in the centre.

King-post Roof.—When it is attempted, however, to apply the last-mentioned construction to large spans, it is found that the weight of the roof covering, of snow, and the pressure of the wind upon the rafters, are too much for them, and that they have a tendency to bend.

It is necessary, therefore, that they should be supported in the middle, and this is done by means of wooden props called "*braces*" or "*struts*" (S S, Fig. 348), which afford a more direct support to the rafters than a collar beam would do.

These struts are placed with their upper ends under each rafter, near its centre point,[2] their lower ends being secured to the vertical tie of the roof.

It is somewhat inconvenient to attach the feet of the struts to an iron rod and therefore the vertical tie in wooden roofs is generally made of timber and called a "*King Post*" or "*King Piece*," the head and feet of which are conveniently shaped to receive the rafters and struts.

The struts *may*, however, be fixed to the foot of an iron king bolt, as shown in Figs. 279 and 354.

The rafters, being now supported in the centre, are reduced to half their former bearing, and are able therefore to bear twice the load that they could before have sustained.

The resulting framework (see Fig. 348), consisting of the rafters (PR), king post (KP), struts (S), and tie beam (T), is known as a *King-post Truss.*

[1] In order to obtain a really stiff ceiling, it is a good plan to introduce heavy tie beams or binders, at intervals of 8 or 10 feet in the length of the roof, supported in the centre by an iron rod, as shown. These beams act as ties, and also carry the ceiling joists, which then run at right angles to them, and are notched to their under side.

[2] With regard to the exact position of the struts, see p. 172.

Such a truss is well adapted for roofs having a span not exceeding 30 feet.

The remaining parts shown in Fig 348, lettered CR, P, B, G, *pp*, and *r*, are not portions of the truss itself, but are supported by it.

It would for many reasons be inconvenient to have trusses such as that just described so close together that they would carry the boarding slates or other roof covering without any intermediate bearers.

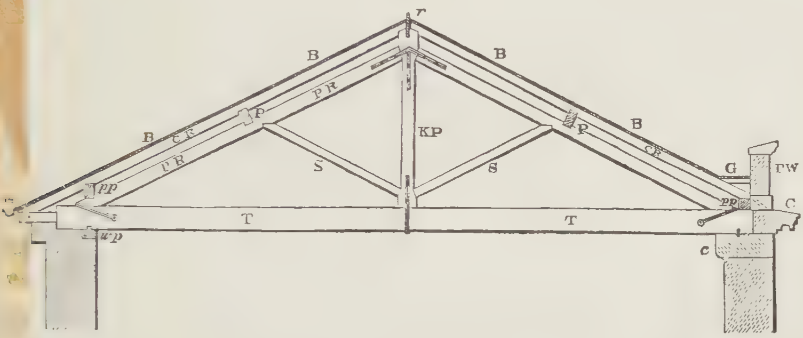


Fig. 348. *King-post Truss.*

Occasionally very light trusses, made simply of narrow pieces of boards nailed together in something like the king-post form, are so used, but the general practice is to set up trusses along the building,[1] about 10 feet apart, and each strong enough to bear the weight of the portion of roof (one "*bay*") that will be carried by it.

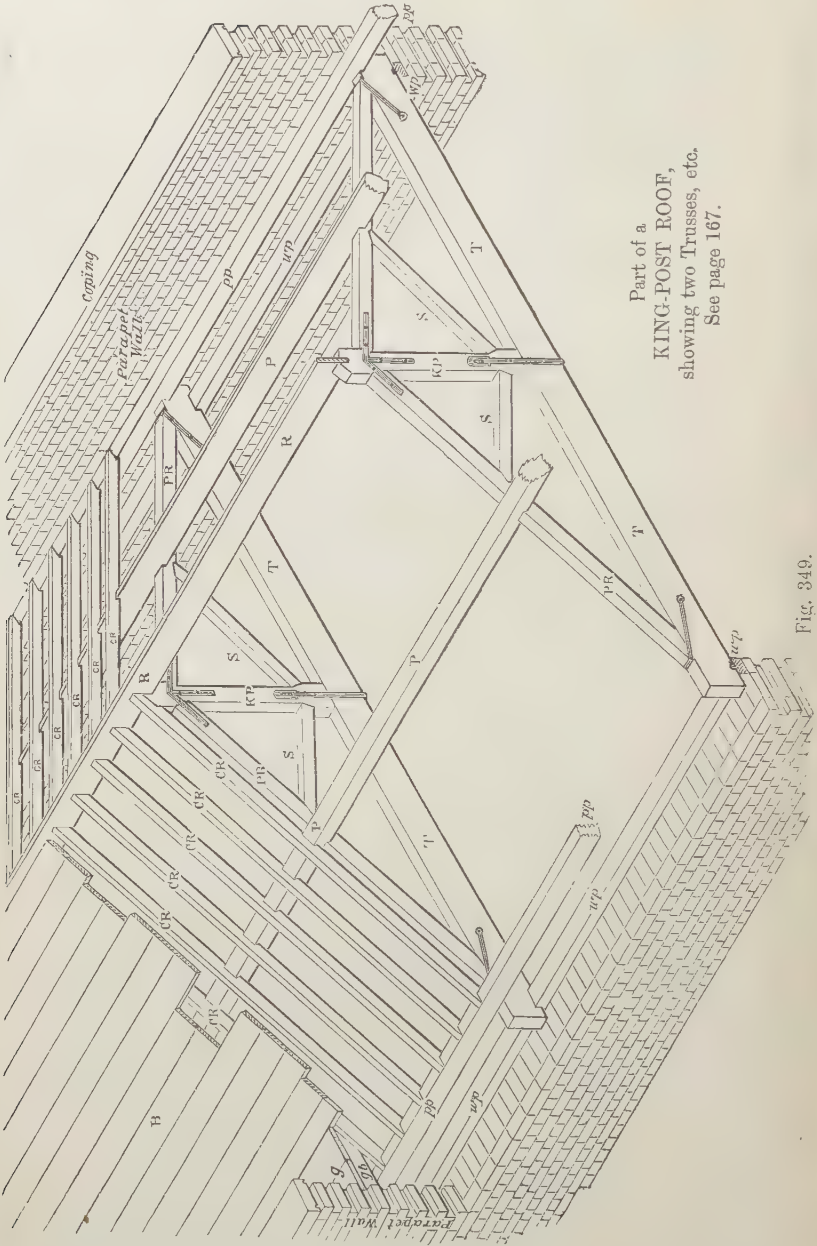
Across these trusses or "*Principals*" are laid *purlins* (PP), and upon the purlins are fixed smaller or "*common rafters*" (CR), which carry the *boarding*, B (or *battens* where they are used), for the slates.

Other members are also found necessary, such as *wall plates* (*wp*) to grip the ends of the tie beam and to distribute the weight over the walls; a *ridge piece* (*r*) to unite the tops of the trusses longitudinally and receive the upper ends of the common rafters; and *pole plates* (*pp*) to receive the feet of the common rafters.

Fig. 349 represents part of a king-post roof showing two principal trusses with some of the members resting upon them, nearly all the boarding being omitted, and also most of the common rafters between the principals, in order that the trusses and purlins may be seen more distinctly.

The walls supporting the roof are surmounted by parapets; part

[1] These should be over the piers between the windows, not over the openings.



Part of a
KING-POST ROOF,
showing two Trusses, etc.
See page 167.

Fig. 349.

of one is broken away in order to show the roof timbers and a portion of the woodwork of the gutter formed behind it.

PARTS OF A KING-POST ROOF.

We will now proceed to consider the different parts of a king-post roof in detail.

The Wall Plates are pieces of timber imbedded in mortar on the tops of the walls to carry the ends of the tie beam and distribute its weight. They are sometimes bolted down to the wall so as to secure the roof in case of wind getting under it and tending to lift it.

The tie beam is sometimes notched or cogged upon them, but is generally only nailed to them.

It is an advantage to have the wall plate over the centre of the wall, so as to bring the weight fairly upon the masonry, but this increases the bearing of the tie beam and causes expense. Wall plates are therefore generally placed so as to be flush with the inner faces of the walls.

At the angles of buildings the wall plates are halved, dovetailed, or notched into one another, and well spiked together, and halved or scarfed wherever it is necessary to join them in the direction of their length: they should, however, be in long pieces, so as to avoid this as much as possible.

In roofs of very wide span two wall plates parallel to one another, and a few inches apart, are sometimes placed on each wall, so as to secure the tie beam more firmly.

Templates are long flat stones frequently substituted with great advantage for wall plates. They are frequently made of wood, but stone has the great advantage of not being subject to decay or destruction by fire.

The tie beams either merely rest upon them or are secured by joggles.

Wall plates which are not continuous, but which are placed under the ends of the trusses in pieces only sufficiently long to distribute the weight, are also sometimes called *templates.*

The Tie Beam.[1]—As far as the roof itself is concerned, this member has nothing to do but to hold in the feet of the rafters to prevent them from spreading, and it would thus be subject only to a tensile stress.

[1] Sc. sometimes called *Tie joist.*

In many cases, however, it carries the ceiling joists (see Figs. 350 to 352), and it has then to bear the cross strain caused by the weight of the ceiling.

To prevent it from sagging or drooping in the centre, the tie beam should be supported at one or more points in its length. As a rule, there should not be more than 12 or 14 feet between the points of support.

In a king-post roof there is only one such point of support, and it is in the centre of the tie beam (see p. 180).

The tie beam receives the feet of the rafters in oblique mortises (see p. 106), the joints being further secured by straps or bolts.

As a point of construction, it is better that the joint between the foot of the rafter and the tie beam should be over the wall, as shown in Figs. 348, 352, instead of within it, as in Figs. 349, 364; but as the latter position allows a wider span between the walls, with the same amount of timber in the roof, it is very frequently adopted.

In such a case, iron, stone, or wood corbels (see Figs. 277, 348) or brackets (Fig. 362) are often provided, so that the bearing of the tie beam is reduced, and support is afforded to it just below the points where the rafters bear upon it.

The ends of the tie beam are notched or cogged, and nailed upon the wall plates, and should be left with a free circulation of air around them. The tie beam is frequently "cambered" in the middle to allow for sagging, so that after it has taken its bearing it may be horizontal. When there are ceiling joists attached to the tie beam, the same object may be effected by keeping them a little higher at the centre (see p. 139, Floors), varying the depth of the notches on their upper sides.

The centre of the tie beam is upheld by being strapped (see Fig. 350) to the king post. The shrinking of the timbers will cause the tie beam to separate from the foot of the king post; the strap should therefore be furnished with adjusting wedges (*c c*, Fig. 351), which can be tightened up to counteract this.

A slot or rectangular hole is made in the strap and through the post, to receive these iron wedges, or, as they are technically called, "*cotters*;"[1] they are enabled to slide easily, and prevented from crushing into or indenting the wood by iron shields above and below called "*gibs*" (*g g*, Fig. 351), which are so formed as to clip the sides of the strap and keep them close to the king post; the

[1] Sometimes called *keys*.

manifest effect of driving the wedges inwards is to raise the upper gib and strap, and with it the tie beam it supports.

Fig. 351 shows the position of the wedges before tightening up.

The slots should be so arranged that there is, before driving the wedges, a space in the king post at *x* above the upper gib, and one in the strap at *y* below the lower gib, so as to admit of the strap being raised until the tie beam is as close up to the king post as possible.

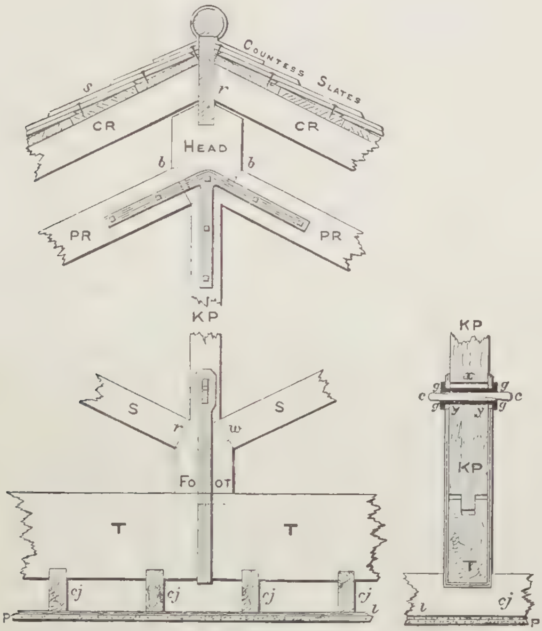


Fig. 350. Fig. 351.

The King Post, or "*King Piece,*" is intended merely as a tie to hold up the centre of the tie beam and prevent it from sagging, for which purpose it is united to it by the strap or stirrup just described.

The head (see Fig. 350) is if possible enlarged, so as to afford a bearing perpendicular to the pressure of the principal rafters (see p. 108), and bevelled and mortised to receive their upper ends, which are tenoned into it.

The top of the head may be left square, as in Fig. 259, when there is no common rafter immediately over the Principal, or

bevelled off parallel to the backs of the common rafters where they occur (Fig. 349). A notch is cut in it to receive the *ridge* (*r*).

The foot (Fig. 350) is similarly arranged to receive the feet of the struts.

The lower the block at the foot of the king post the better will the struts be placed for taking the strain upon them.

The head of the king post sometimes becomes so compressed by the rafters that the fibres are crushed, and the post sinks, allowing the tie beam to sag. On this account oak king posts have been used, as they are less compressible, and it is a strong reason in favour of king bolts.

Any shrinkage in the width of the king post will cause the rafters to come nearer together at the head, and the struts to do the same at the foot.

It is therefore necessary that the head of the king post and of the principal rafters should be fastened together with straps as shown. Occasionally provision is made for tightening the joint by means of gibs and cotters similar to those for the foot of the king post described at p. 171.

The joints between the ends of the principal rafters and the head of the king post should be left a little open at *b b*, Fig. 350, so as to allow the ends of the rafters to bear inwards when the roof settles, without crushing the angles at *b b*.

The foot of the king post is kept in position by a stub tenon, and secured to the tie beam either by a strap with adjusting wedges, as above described; or by a common stirrup; or by a bolt passing through the tie beam and secured into a nut fixed within the king post; or by a very bad arrangement consisting of a dovetailed tenon penetrating the whole depth of the tie beam, and secured by a wedge as described at p. 106.

When the truss is first put together, the foot of the king post should be kept well clear of the tie beam, so that in case of a general depression of the roof it may not bear upon it. The tie beam is raised by the adjustment of the cottered joint after the roof has taken its bearing.

Suspending Pieces, as described at p. 111, may sometimes be used instead of king posts.

The Struts[1] prevent the principal rafters from sagging in the middle. In order to guard against any cross strain whatever coming upon the rafters, the heads of the struts should be almost

[1] Also called *Braces*.

immediately under the purlins[1] (see Fig. 352), but this cannot always be arranged without inclining the struts at too flat an angle. The more upright they are, the better they are placed for bearing the strain upon them.

The heads of the struts are tenoned into the principal rafters, as shown in Fig. 352, and their feet into the foot of the king-post.

The struts, being under compression,[2] should be made of full length and of very dry stuff, for unless well seasoned they will shrink (even in length) and allow the rafters to bend.

The Principal Rafters are tenoned at the upper end into the head of the king post (Fig. 350), and at the lower end into the tie beam, as shown in Fig. 352 and at p. 107, the joints being secured by straps or bolts, as described at pages 110 and 115.

The heads are sometimes secured in cast-iron sockets, and the feet in shoes (see p. 118).

The principal rafters carry the purlins, which are notched to fit them, the back of the rafter being sometimes cogged to receive the notch.

Each principal rafter is supported near its centre, close below the purlin, by a strut tenoned into it, as shown in Fig. 352.

This halves the bearing, and therefore greatly increases the strength and stiffness of the rafter.

A shrinkage in the depth of the rafters will cause them to sag, or to separate from the struts. If they shrink in length, the king post will subside between them, and will tend to bear upon the tie beam instead of holding it up.

The **Purlins**[3] are beams running longitudinally from Principal to Principal as supports for the common rafters.

They are sometimes framed in between the principal rafters, but this weakens the latter and is a bad construction.

The purlins are generally notched where they rest upon the principal rafters, so as to keep the latter rigidly apart; but if a cog is formed upon the back of the rafter it should be very wide, so as to leave the latter as nearly intact as possible.

As an additional precaution, the purlins are supported by blocks of wood (*cl*, Fig. 352) called "*cleats*," which may be housed into the backs of the rafters, as shown in Fig. 352, or merely spiked to them, as in Fig. 353.

[1] The centre lines of the strut and rafter and the resultant of the forces acting on the purlin should if possible intersect in one point as in Plate 7 of Part IV. Fig. 380, but this condition cannot always be realised in practice.

[2] See Part IV. [3] In some parts of England called *side timbers* or *side wavers*.

The best position for purlins is immediately over the head of the strut, as before mentioned (see p. 173 and Fig. 352), in order that they may cause no cross strain on the principal rafters; but they are generally placed (see Fig. 348) so as to support the common rafter at equal intervals, without reference to their exact position as regards the struts, the heads of which are placed as nearly under them as possible.

Two purlins are frequently used on each slope of the common king-post roof (see Fig. 353), and are necessary when the common rafters are so long as to require support at more than one intermediate point; in such a case, however, a queen-post truss should be used.

Purlins should be used in as great lengths as possible,[1] but when the roof is a long one they necessarily require to be "scarfed" or "fished." It is better to connect the lengths of the purlin by butt joints fished on each side than by scarfing them. The latter, however, is the most usual practice. Each purlin should, however, in any case extend over at least two "bays,"[2] and the scarf should in every case be immediately over a principal truss or partition wall.

In some cases the Principals are placed at considerable distances apart, and the purlins trussed to span the intervals.

When several purlins are fixed on each side of the roof at intervals of a few inches, so as themselves directly to receive the boarding or roof covering, they become in effect horizontal rafters.

The Ridge Piece is a board from 1 to $2\frac{1}{2}$ inches thick (R, Fig. 350) let into the head of the king post and running throughout the length of the roof; against it the common rafters abut.

If the ridge is to be covered with lead, it is surmounted by a long cylindrical piece of wood called the *Ridge roll*[3] (see Figs. 350, 438); but with slate or earthenware ridging the roll is not necessary, and the ridge piece is simply blocked off to fit the covering intended (see Fig 414).

The Common Rafters[4] are bevelled at the upper end to abut against the ridge piece, and are nailed to it. They may be notched out to fit the head of the king post, as in Fig. 349, or they may pass above it, as in Fig. 350. In the centre they are notched

[1] The reasons for this will be explained in Part IV.

[2] A "bay" is the interval between two Principals.

[3] Sc. sometimes called *Ridge pole*.

[4] Sc. *Spars*.

to fit the purlin, and at the lower end nailed and generally notched upon the pole plate.

They should, of course, always be in one piece, and are generally made about 2 inches broad, and placed about 12 inches apart.

In roofs with projecting eaves[1] the lower ends of the common rafters are carried beyond the pole plate, and the eaves gutter is fixed to them (see Fig. 352).

When the common rafters are broken through by a chimney or other obstacle upon which they cannot rest, they should be trimmed round it in the same way as floor joists are trimmed round a fireplace (see p. 121) or other opening. The section, Fig. 427, shows an example of this.

The trimmers (*t t*, Fig. 427) are sometimes placed vertically, but the best and strongest method is to fix them at right angles to the rafters, as shown.

The rafters are generally notched on to the trimmers instead of being tenoned into them, and the trimmer is often supported by a corbel protruding from the chimney.

The common rafters are sometimes placed as purlins horizontally, parallel to the ridge, in which case heavy timbers are avoided, and the Principals are more rigidly connected.

The Roof Boarding[2] is nailed upon the common rafters to receive the slates or other covering.

It is generally placed horizontally, running parallel to the ridge; but, in some cases, is made to lie diagonally across the rafters.

When the rafters are placed horizontally, the boarding, of course, runs down the slope of the roof; thus its ends instead of its sides are presented to the descending wet, and it is more likely to be preserved from decay.

The boarding is often covered with felt, which is a non-conductor of heat and cold, and, moreover, keeps the roof dry in case of any failure in the slating.

BATTENS are frequently used in common roofs to carry the slates or tiles. If so, they are nailed at right angles to the common rafters, parallel to one another, and at the "gauge" or distance apart required for the covering to be used (see p. 217, and Fig 413).

The Pole Plates[3] generally rest on the ends of the tie beams, being as a rule notched and spiked to them, and run parallel to the length of the roof. They receive the ends of the

[1] The eaves of a roof are the lower edges of the side slopes.

[2] Sc. *Sarking*.

[3] Sc. *Poll plate*.

common rafters, which are generally birdsmouthed, to fit upon the plate.

The pole plate is usually placed immediately over the wall plate, so that the weight upon it is transmitted directly through the latter to the wall (see Figs. 348, 349), but in some cases the position has to be altered. For instance, in Fig. 352, where the

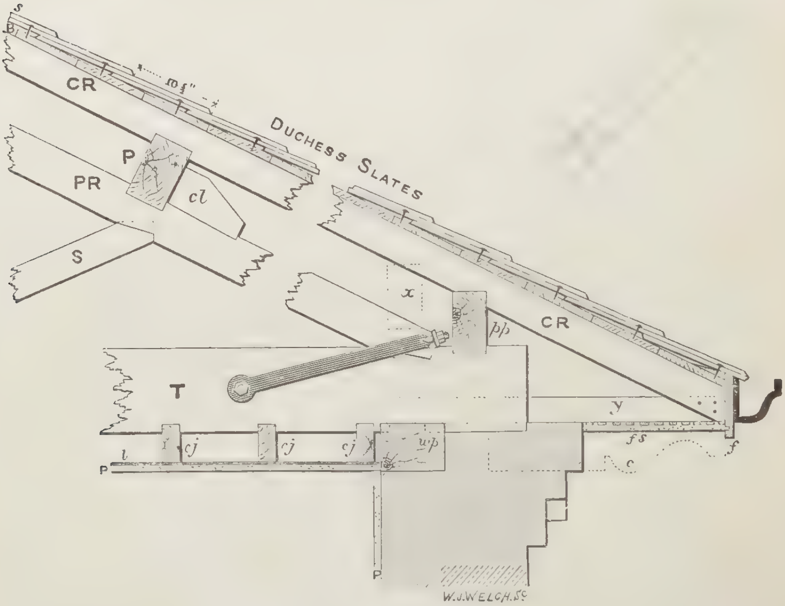


Fig. 352.

joint between the rafter and tie beam rests upon the wall, the pole plate, in order to be immediately over the wall plate, would necessarily be placed so as to cut into and weaken the principal rafter as shown in dotted lines.

This position for the pole plate, though objectionable for the reason stated, is sometimes advisable—for example, in the case where room is required to form a gutter between it and the blocking course (see Fig. 435), or in the valley between two roofs where a wide gutter is required (Fig. 431).

Generally speaking, the position and size of the pole plates depend upon the form of the roof, method of fixing the gutters, etc., and are very varied.

Ceiling Joists.—When a ceiling is required, the joists to sup-

port it are generally notched and nailed to the under side of the tie beam, as shown in Figs. 350 to 352.

Ceiling joists attached to roofs are similar to those fixed below floors, as described at p. 139.

The Eaves are the lower edges of the slopes of a roof. They may project over the walls, as in Figs. 346, 352; or they may finish upon an iron gutter on the top of the wall, as in Fig. 411; or upon a lead gutter formed behind a blocking course, or a parapet wall, as in Figs. 427, 435.

When the eaves project considerably, as in Fig. 352, "*Planceer pieces*" (y) may be fixed to support the *Soffit* or *Planceer*, which is formed either by boarding the under sides of the joists, or by lathing and plastering them as shown.

In some cases the soffit is supported by *Eaves corbels, Cantilevers,* or *Consoles* (as dotted at c), built into the wall.

A *Fascia Board* (f) is fixed to the ends of the rafters, and to it the gutter is attached. When the eaves project only a few inches, the Planceer pieces (y) become unnecessary, and the roof is finished as in Fig. 346.

Gutters.—It is necessary to provide for carrying off the rain-water and snow from the roofs, to prevent them from running over the face of the building, and in many cases to collect them for storage and use.

This is effected by gutters of different forms leading to vertical rain-water pipes, which latter conduct the water to drains provided for it. Some of the principal forms of iron and lead gutters are described in Chap. XIV. under the head of Plumbers' Work.

Wooden gutters are sometimes used in the country, or for very temporary buildings. They consist merely of V-shaped or rectangular channels made of boards nailed together, and require no further description.

Queen-post Roofs are more fully referred to in Chap. XI., and Figs. 364 to 366 on p. 187 should be referred to in connection with the tables of scantlings of timber which follow.

Sizes of Roof Timbers.—Tredgold's Scantling.—The following table, from Tredgold's *Carpentry*, gives the *scantlings* (or sizes) of timbers for King-post roofs with ceilings. The trusses are supposed to be not more than 10 feet apart, the pitch of the roof about $\frac{1}{4}$ or 27°, the covering slates, and the timber Baltic fir.

King-post Roofs.—Table of Scantlings of Timber, recommended by Tredgold,[1] for different spans, from 20 to 30 feet.

Span.	Tie Beam, T.	King Post, KP.	Principal Rafters, PR.	Braces or Struts, S.	Purlins, P.	Common Rafters, CR.
20 feet.	9½ by 4	4 by 3	4 by 4	3½ by 2	8 by 4¾	3½ by 2
22 ,,	9½ ,, 5	5 ,, 3	5 ,, 3	3¾ ,, 2¼	8¼ ,, 5	3¾ ,, 2
24 ,,	10½ ,, 5	5 ,, 3½	5 ,, 3½	4 ,, 2½	8½ ,, 5	4 ,, 2
26 ,,	11½ ,, 5	5 ,, 4	5 ,, 4¼	4¼ ,, 2½	8¾ ,, 5	4¼ ,, 2
28 ,,	11½ ,, 6	6 ,, 4	6 ,, 3½	4½ ,, 2¾	8¾ ,, 5¼	4½ ,, 2
30 ,,	12½ ,, 6	6 ,, 4½	6 ,, 4	4¾ ,, 3	9 ,, 5½	4¾ ,, 2

Queen-post Roofs, such as in Fig. 364.—Tables of Scantlings of Timber for different Spans, from 32 to 46 feet.

Span.	Tie Beam, T.	Queen Post, QP.	Principal Rafters, PR.	Straining Beam, SB.	Struts, S.	Purlins, P.	Common Rafters, CR.
32 ft.	10 by 4½	4½ by 4	5 by 4½	6¾ by 4½	3¾ by 2¼	8 by 4¾	3½ by 2
34 ,,	10 ,, 5	5 ,, 3½	5 ,, 5	6¾ ,, 5	4 ,, 2½	8¼ ,, 5	3¾ ,, 2
36 ,,	10½ ,, 5	5 ,, 4	5 ,, 5¾	7 ,, 5	4¼ ,, 2½	8½ ,, 5	4 ,, 2
38 ,,	10 ,, 6	6 ,, 3¾	6 ,, 6	7¼ ,, 6	4½ ,, 2½	8½ ,, 5	4 ,, 2
40 ,,	11 ,, 6	6 ,, 4	6 ,, 6	8 ,, 6	4½ ,, 2½	8¾ ,, 5	4¼ ,, 2
42 ,,	11½ ,, 6	6 ,, 4½	6¼ ,, 6	8¼ ,, 6	4½ ,, 2¾	8¾ ,, 5¼	4½ ,, 2
44 ,,	12 ,, 6	6 ,, 5	6½ ,, 6	8½ ,, 6	4½ ,, 3	9 ,, 5	4¾ ,, 2
46 ,,	12½ ,, 6	6 ,, 5½	7 ,, 6	9 ,, 6	4¾ ,, 3	9 ,, 5½	5 ,, 2

With regard to these tables it should be mentioned that the dimensions given are a safe guide, erring, if at all, on the side of excess of strength. The scantlings for the tie beams may be considerably reduced when there are no ceiling joists attached to them. In practice the width of the King and Queen Posts, Principal Rafters, and Struts is generally made the same as that of the tie beam.

Lighter Scantlings for Roofs.—The following tables give scantlings for roofs which have been adopted in a large number of War Department buildings. They will be found to be much lighter and more economical than those given by Tredgold.

SCANTLINGS FOR WOODEN ROOFS.

The roofs are supposed to be of Baltic fir covered with Countess slates laid on inch boards; the maximum horizontal wind force is taken at 45 lbs. per foot super, acting only on one side of the roof at a time, equivalent to a normal wind pressure of 30 lbs. per square foot for a pitch of 30°, and 40 lbs. per square foot for a pitch of 45°.

The common rafters to be 1 ft. from centre to centre, but in sheltered positions they may be placed 1 ft. apart in the clear.

[1] Tredgold's formulæ for the scantlings of King and Queen Post Roofs are given in Chap. XI.

Roofs without Ceilings.—Pitch up to 30°.

	Span	‡ Tie Beam. *Depth includes 3″ for joints.*	Principal Rafters.	King Post.	Struts.	Straining Beam.	§ Purlins. 10 *ft. bearing.*	Common Rafters.
King Post. *Trusses 10′ centre to centre.*	20	3″ × 4½″	3″ × 5″	3″ × 2¾″	3″ × 3″	–	5″ × 7½″	2″ × 3½″
	22	3″ × 4¾″	3″ × 5½″	3″ × 2¾″	3″ × 3½″	–	5″ × 7¾″	2″ × 3¾″
	24	3½″ × 4½″	3½″ × 5¼″	3½″ × 2¾″	3½″ × 3½″	–	5″ × 8″	2″ × 4″
	26	3½″ × 4¾″	3½″ × 5¾″	3½″ × 2¾″	3½″ × 4″	–	5″ × 8¼″	2″ × 4¼″
	28	4″ × 4½″	4″ × 5½″	4″ × 2¾″	4″ × 4″	–	5″ × 8½″	2″ × 4½″
	30	4″ × 4¾″	4″ × 6″	4″ × 2¾″	4″ × 4½″	–	5″ × 8¾″	2″ × 4¾″
				Queen Posts.				
Queen Post. *Trusses 10′ centre to centre.*	32	4½″ × 4½″	4½″ × 4¾″	4½″ × 2¾″	4½″ × 2½″	4½″ × 5½″	5″ × 7½″	2″ × 3½″
	34	4½″ × 4¾″	4½″ × 5″	4½″ × 2¾″	4½″ × 2¾″	4½″ × 6″	5″ × 7¾″	2″ × 3¾″
	36	4¾″ × 4¾″	4¾″ × 5″	4¾″ × 2¾″	4¾″ × 3″	4¾″ × 6¼″	5″ × 8″	2″ × 4″
	38	4¾″ × 4¾″	4¾″ × 5¼″	4¾″ × 2¾″	4¾″ × 3¼″	4¾″ × 6¾″	5″ × 8″	2″ × 4″
	40	4¾″ × 5″	4¾″ × 5½″	4¾″ × 2¾″	4¾″ × 3¼″	4¾″ × 7¼″	5″ × 8¼″	2″ × 4¼″
	42	5″ × 5″	5″ × 5½″	5″ × 2¾″	5″ × 3¼″	5″ × 7½″	5″ × 8½″	2″ × 4½″
	44	5″ × 5¼″	5″ × 5¾″	5″ × 2¾″	5″ × 3½″	5″ × 8″	5″ × 8½″	2″ × 4¾″
	46	5¼″ × 5¼″	5¼″ × 5¾″	5¼″ × 2¾″	5¼″ × 3½″	5¼″ × 8¼″	5″ × 8¾″	2″ × 5″

Roofs with Ceilings.—Pitch up to 30°.

Nature of Roof.	Span in feet.	Common Rafters.		* Collar.				
Collar Beam.	8 to 18.	Add ¼″ to the depths given in Table for Roofs without Ceilings.		Add ¾″ to depths given in Table above.	* In fixing the collar to the rafter, the latter should not be cut into. As regards walls capable or not capable of resisting the thrust of roof see remarks, p. 157.			
		‡ Tie Beam.	Principal Rafters.	King Post.	Struts.	Straining Beam.	§ Purlins. 10 *ft. bearing.*	Common Rafters.
King Post. *Trusses 10′ centre to centre.*	20	4″ × 7″	4″ × 4″	4″ × 3″	4″ × 2½″	–	5″ × 7½″	2″ × 3½″
	22	4″ × 7½″	4″ × 4½″	4″ × 3″	4″ × 3″	–	5″ × 7¾″	2″ × 3¾″
	24	4¼″ × 8″	4¼″ × 4¾″	4¼″ × 3″	4¼″ × 3″	–	5″ × 8″	2″ × 4″
	26	4½″ × 8½″	4½″ × 5″	4½″ × 3″	4½″ × 3″	–	5″ × 8¼″	2″ × 4¼″
	28	4½″ × 9″	4½″ × 5½″	4½″ × 3″	4½″ × 3½″	–	5″ × 8½″	2″ × 4½″
	30	4¾″ × 9½″	4¾″ × 5¾″	4¾″ × 3″	4¾″ × 3¾″	–	5″ × 8¾″	2″ × 4¾″
				Queen Posts.				
Queen Post. *Trusses 10′ centre to centre.*	32	4¾″ × 7¼″	4¾″ × 5½″	4¾″ × 3″	4¾″ × 2½″	4¾″ × 6¾″	5″ × 7¾″	2″ × 3½″
	34	4¾″ × 7¾″	4¾″ × 5¾″	4¾″ × 3″	4¾″ × 2¾″	4¾″ × 7½″	5″ × 7¾″	2″ × 3¾″
	36	4¾″ × 8¼″	4¾″ × 6¼″	4¾″ × 3″	4¾″ × 3″	4¾″ × 8¼″	5″ × 8″	2″ × 4″
	38	5″ × 8½″	5″ × 6″	5″ × 3″	5″ × 3″	5″ × 8¼″	5″ × 8″	2″ × 4″
	40	5″ × 9″	5″ × 6½″	5″ × 3½″	5″ × 3¼″	5″ × 9″	5″ × 8¼″	2″ × 4¼″
	42	5½″ × 9″	5½″ × 6¼″	5½″ × 3½″	5½″ × 3″	5½″ × 9″	5″ × 8½″	2″ × 4½″
	44	5½″ × 9½″	5½″ × 6¾″	5½″ × 3½″	5½″ × 3¼″	5½″ × 9½″	5″ × 8½″	2″ × 4¾″
	46	5½″ × 10″	5½″ × 7¼″	5½″ × 4″	5½″ × 3½″	5½″ × 10″	5″ × 8¾″	2″ × 5″

For roofs of 45° pitch.—Add 1″ to the depth of common rafters, purlins, and struts, and ½″ to the depth of the principal rafters, as given in above Tables.

§ If *the purlins,* instead of being placed immediately over the joints, are placed at intervals along the principal rafter, increase the depth of the latter, given in the tables, as follows :—

King-post roof $\begin{cases} \textit{without} \text{ ceiling } 2'' \\ \textit{with} \quad ,, \quad 1\frac{1}{2}'' \end{cases}$ Queen-post roof $\begin{cases} \textit{without} \text{ ceiling } 1\frac{1}{4}'' \\ \textit{with} \quad ,, \quad \frac{1}{2}'' \end{cases}$

The purlins if placed 2 feet apart and with 10 feet bearing may be made $3'' \times 6''$.

The scantlings of the principal rafters, struts, and straining beam can be *slightly* modified by means of the following rough rule: "For every $\frac{1}{4}''$ deducted from the *lesser* dimension of the scantling, add $\frac{1}{2}''$ to the other dimension, and *vice versâ*." For the tie beam, purlins and common rafters, so long as the depth is about double the breadth, $\frac{1}{4}''$ deducted from the breadth requires $\frac{1}{4}''$ to be added to the depth.

‡ *The joint of the tie beam with the principal rafter* should be placed immediately over the supporting wall. If this cannot be conveniently done, the depth of the tie beam should be increased one or two inches.

These Tables, compiled by Major H. C. SEDDON, R.E., from calculations by Lieut. H. R. SANKEY, R.E., have been followed in the construction of a large number of W.D. buildings.

Several points connected with roofs, such as the formation of Hips and Valleys, the trimming of rafters round chimneys, etc., are referred to in Chap. XI., pp. 185 to 201.

ROOFS OF WOOD AND IRON COMBINED.

As the tensile strength of iron is much greater than that of timber, it is generally preferable to use the former for any member exposed to tensile stresses only.

Iron king rods would, as before mentioned, probably have come into general use, but that it is difficult to make a simple and good joint where the feet of the struts rest against them.

Iron tie rods would also be preferred to timber tie beams, if it were not that these often have to carry ceiling joists, which could not conveniently be fixed to iron rods.

In some roofs, however, the first difficulty above mentioned has been overcome; when no ceiling is required the second does not exist, and a judicious combination of iron and wood has been effected.

King-rod, or King-bolt Roof (Wooden Tie).—In the roof, Fig. 353, a wooden tie beam is retained to carry a ceiling, but a king bolt is used, and the difficulty in forming a joint for the struts at its feet is avoided by the use of a straining piece (SP).

In roofs of a greater span than 24 feet,[1] the tie beam may be supported at intermediate points by similar bolts hanging from the points where the struts meet the rafters.

[1] See p. 170.

A further use of iron is here exemplified in the shape of a cast-

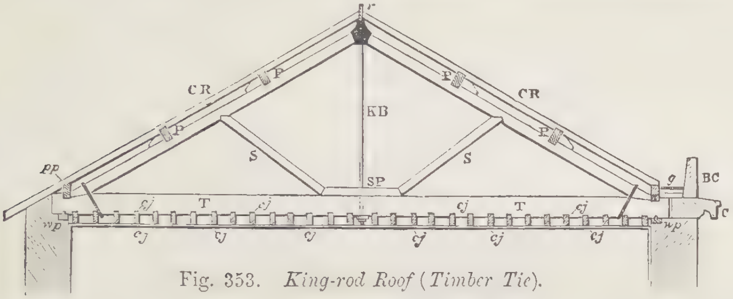


Fig. 353. *King-rod Roof (Timber Tie).*

iron socket to receive the upper ends of the rafters and the king bolt.

It will be noticed that the principal rafter carries two purlins, an arrangement which produces a cross strain upon the principal rafters. The tie beam carries ceiling joists to support a lathed and plastered ceiling.

King-bolt Roof (**Iron Tie**).—Fig. 354 shows a roof of which

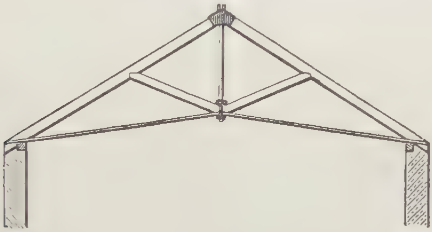


Fig. 354. *King-rod Roof (Iron Tie).*

both the king bolt and tie rod are iron. The struts abut against one another, and rest upon a nut at the lower end of the king bolt, which can be screwed up so as to tighten the roof if necessary.

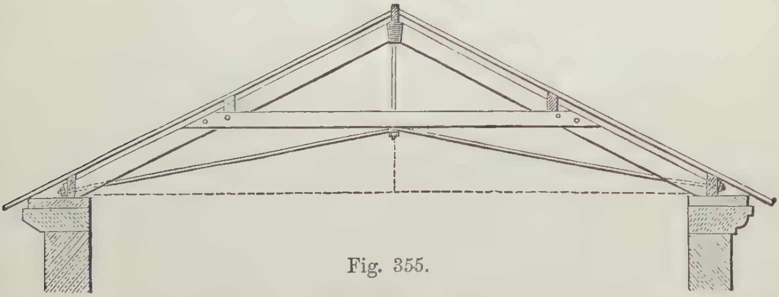


Fig. 355.

Collar-beam Roof.—In the roof shown in Fig. 355 an attempt

is made to remedy the great defect of the ordinary collar-beam construction by providing tension rods to hold in the feet of the rafters. The more nearly horizontal these tension rods are made, the better is their object fulfilled.

When the feet of the rafters are firmly held in by a tie rod in a horizontal position, as dotted, the collar beam becomes permanently a strut, and the construction is a good one.

The ends of the tension rods and of the king bolt are furnished with screws and nuts, by which they can be tightened up when required.

Those of the tension rods pass through the lower extremities of the rafters, and through plates which abut against the feet of the rafters and extend the whole length of the wall. The upper end of the king bolt is received by a cast-iron socket.

Trussed-rafter Roof.—In the roof shown in Fig. 356 each

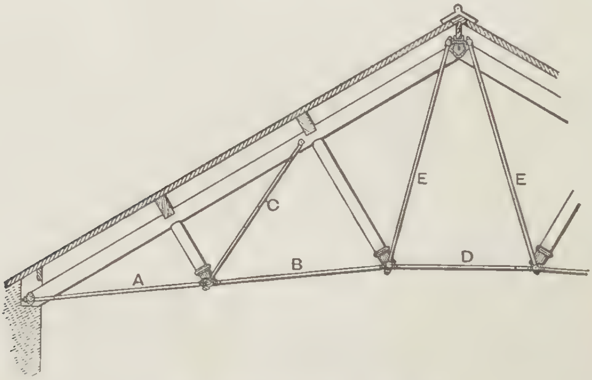


Fig. 356. *Trussed-rafter Roof (Holt's).*

principal rafter is trussed by means of two timber struts supported by tension rods. The connections are formed with cast-iron joints

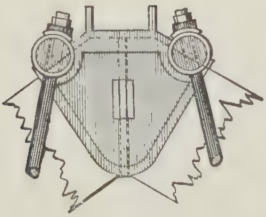


Fig. 357.

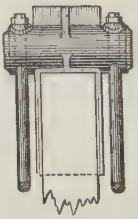


Fig. 358.

Head.

as shown in the details Figs. 357 to 360. The truss in Fig.

356 is for a 35-feet span. The table below shows the scantlings and number of struts used for other spans.

Such roofs are known as *Holt's Roofs*, and are especially suited

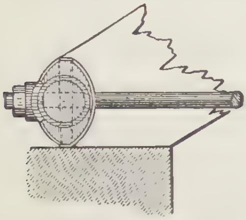


Fig. 359. *Foot of Principal Rafter.*

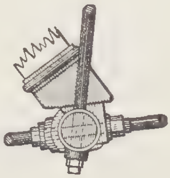


Fig. 360. *Foot of Strut.*

for use in new countries. The iron members are obtainable from stock for spans of from 20 to 50 feet, the timber requires but little preparation, the cost is smaller, and the roofs can be easily erected by unskilled labour.[1]

TABLE OF TIE RODS AND TIMBERS FOR HOLT'S ROOFS.

Form of Truss, see Plate III.	Span.	Wrought-iron Tie Rods.									Rafters.	Struts on each side.	
		A	B		C		D		E				
		Diam.	No.	Diam.	No.	Diam.	No.	Diam.	No.	Diam.	Size.	No.	Size.
Fig. 343	20	$\frac{5}{8}$	...	$\frac{3}{4}$	4	$\frac{5}{8}$	...	...	...	...	7×3	1	3×3
Fig. 343	25	$\frac{5}{8}$	...	$\frac{3}{4}$	4	$\frac{5}{8}$	...	...	...	...	,,	,,	,,
Fig. 345	30	$\frac{3}{4}$	1	$\frac{13}{16}$	4	$\frac{5}{8}$	...	...	...	...	,,	,,	,,
Fig. 346	35	$\frac{3}{4}$	2	$\frac{7}{8}$	4	$\frac{5}{8}$	2	$\frac{5}{8}$	4	$\frac{3}{8}$	,,	,,	,,
Fig. 346	40	$\frac{13}{16}$	2	$\frac{7}{8}$	4	$\frac{5}{8}$	2	$\frac{3}{4}$	4	$\frac{3}{8}$	9×3	1 1	3×3 $3\frac{1}{2} \times 3\frac{1}{2}$
Fig. } 3 struts	45	$\frac{7}{8}$	2	$1\frac{1}{8}$	4	$\frac{5}{8}$	2	$\frac{3}{4}$	4	$\frac{5}{8}$	,,	,,	,,
Fig. } 3 struts	50	$\frac{7}{8}$	2	$1\frac{1}{4}$	4	$\frac{5}{8}$	2	$\frac{3}{4}$	4	$\frac{5}{8}$	9×4	2 1	4×4 3×3

In this country cast-iron struts are frequently used for such roofs, as in Fig. 361, which shows part of a Trussed Rafter with one strut.

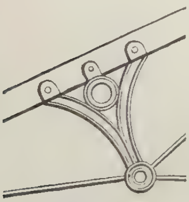


Fig. 361.
Cast-iron Strut.

Queen-rod or Queen-bolt Roof.—Fig. 362 gives the elevation of a roof principal over a station shed, which has been referred to as a good combination of wood and iron. The feet of the suspending bolts and of the struts are here received by cast-iron shoes. A cast-iron socket carries the head of the king bolt, and a bracket of the same material supports the end of the tie beam.

[1] *S.M.E. Course.* The illustrations are from the price lists of the manufacturers, Messrs. Handyside of Derby.

It will be observed that the boarding of this roof is carried upon a number of horizontal common rafters or purlins.

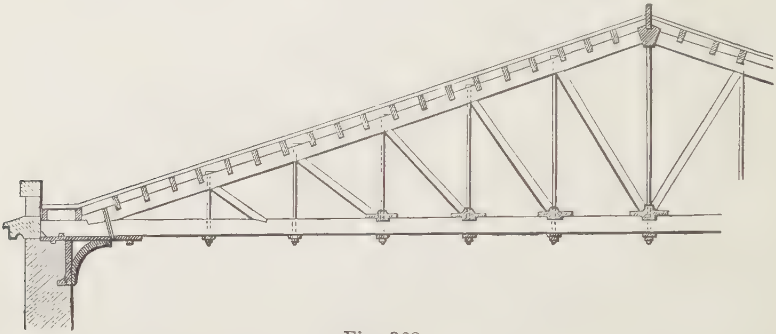


Fig. 362.

The tie beam is supported at a great number of points, which renders it peculiarly adapted for carrying a ceiling.

This roof is shown for the sake of illustrating some of the parts, but such a truss would in these days, as a rule, be formed entirely of mild steel and with a smaller number of parts.

Trusses such as those shown in Figs. 355, 356, and 362 would, of course, be placed at intervals, as the trusses are in Fig. 349.

CHAPTER XI.

CARPENTRY—(*Continued*).

TIMBER ROOFS.

(*Continued from Chapter X.*)

THE king-post roof and simpler forms described in the preceding chapter are adapted for spans up to 30 feet.

The Trusses now to be described are those ordinarily used for spans of from 40 to 60 feet.

Gothic and other roofs adapted for special styles of architecture, or for particular situations, will not be referred to.

Trusses involving the use of curved or built-up beams are also excluded.

N.B.—In all the figures illustrating timber roofs, the distinctive letters for different parts are as follows :—

Angle Tie	*a*	Pole Plate	*pp*
Battens	*b*	Princess Post	*PP*
Binders	*Bi*	Purlin	*P*
Blocking Course	*Bc*	Rafters, Principal	*PR*
Boarding	*B*	,, Common	*CR*
Ceiling Joists	*Cj*	,, Jack	*JR*
Cleats	*C*	Ridge	*r*
Collar Tie	*CT*	Soffit	*fs*
Cornice	*c*	Struts	*S*
Fascia	*F*	Slates	*s*
Gutter	*G*	Straining Beam	*SB*
Gutter-bearer	*gb*	,, Sill	*SS*
Gutter-plate	*gp*	Templates (wall)	*wt*
King Bolt	*KB*	Tie Beam	*T*
,, Post	*KP*	Tilting Fillet	*tf*
Queen Bolt	*QB*	,, Batten	*tb*
,, Post	*QP*	Truss (Principal)	*TP*
Parapet Wall	*PW*	Wall Plates	*wp*

King and Queen Post Roofs.—King-post trusses will do very well for roofs up to about 30 feet span, but for wider roofs it is found that the tie beam requires support at more than the one central point; additional vertical ties, called queen posts, have therefore to be introduced, as at QP, QP, Fig. 363.

The common rafters being longer, require support at more than

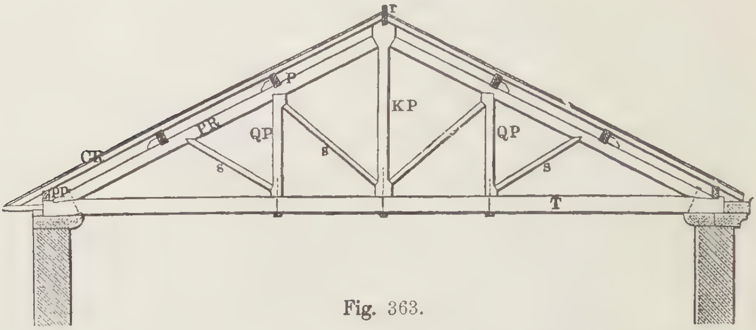


Fig. 363.

one point, two purlins are therefore introduced on each side of the roof.

Queen-Post Roof with King Bolts.—This excellent construction is shown in Fig. 383, p. 197.

When a flat top is not required, purlins with common rafters running down the slope of the roof are adopted, as in Fig. 363, and the apex of the roof finished as there shown.

Queen-Post Roofs.—When rooms have to be formed in the roof, and frequently besides, the king post is omitted, in which case, to prevent the heads of the queen posts from being forced inwards, a straining beam is placed between them, as shown at SB in Fig. 364, and their feet are kept apart by a straining sill, SS.

This form of roof is well adapted for spans of from 30 to 45 feet.

The ends of the straining beam sometimes receive additional support from cleats, as at C, secured to the queen posts. The strap above C is omitted in the figure in order to show the joint.

Roof with Queen Posts and Princesses.—In roofs of a greater span than 45 feet, the tie beam requires to be upheld at more than two intermediate points.

The extra support necessary is furnished by the introduction of additional suspending posts, PP, known as *Princesses*.

Such a construction as that shown in Fig. 367 may be used for spans between 45 and 60 feet.

In roofs of above 50 feet span the straining beam between the heads of the queen posts is so long that it would sag without support, and this may be afforded by means of a small king tie, suspended from the junction of the principal rafters, which are prolonged above the straining beam, as dotted in the figure.

Fig. 366.

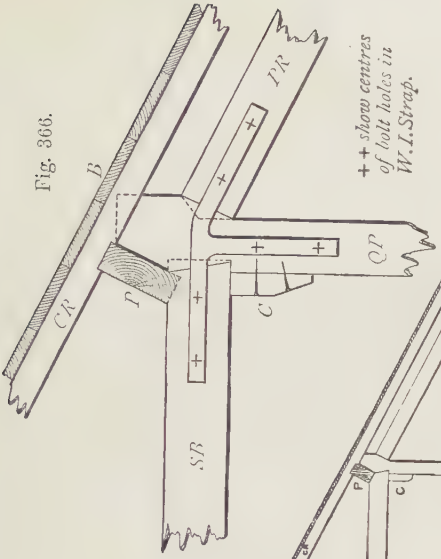
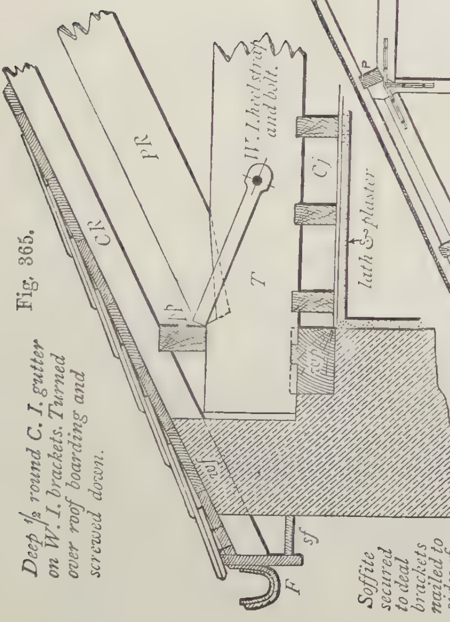


Fig. 365.



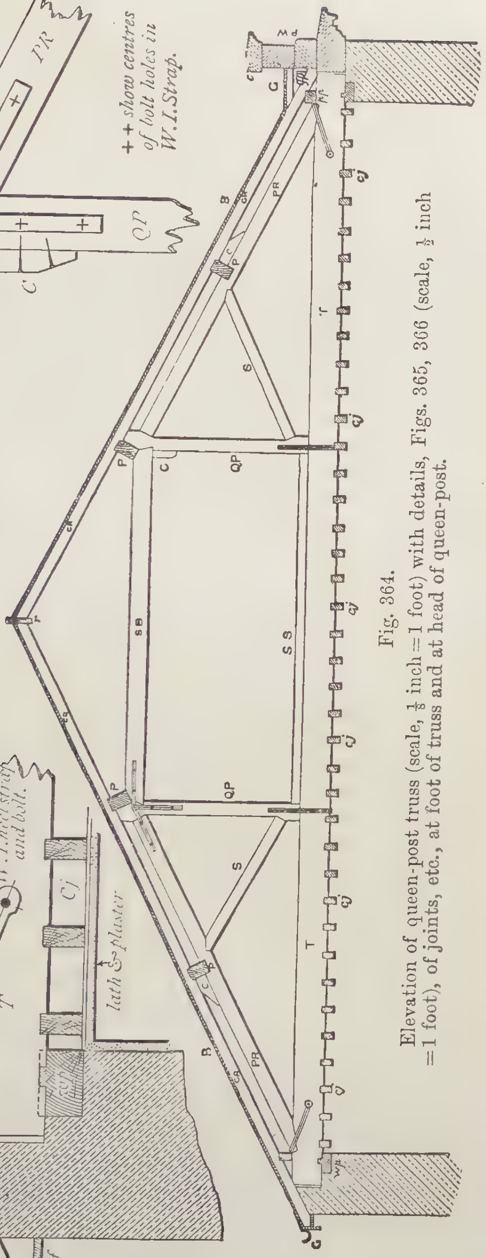


Fig. 364.

Elevation of queen-post truss (scale, $\frac{1}{8}$ inch = 1 foot) with details, Figs. 365, 366 (scale, $\frac{1}{2}$ inch = 1 foot), of joints, etc., at foot of truss and at head of queen-post.

In a roof of this kind the space between the queen posts affords convenient accommodation.

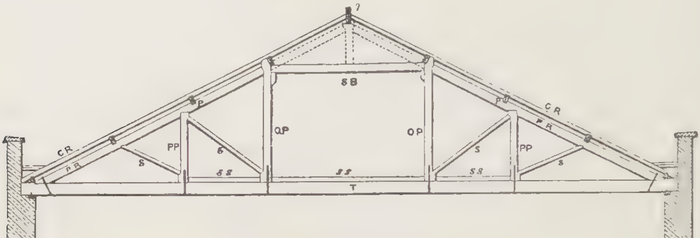


Fig. 367.

Roofs of Spans greater than 60 Feet.—The consideration of such roofs does not fall strictly within the limits of this volume, and in these days they would generally be constructed of steel; it will be sufficient, therefore, to give a few skeleton examples of old timber roofs of large span, before dismissing the subject.

In these figures the lines all represent timber in scantling, framed and put together in a similar way to the members of the trusses depicted in Figs. 363-367.

Fig. 368 nearly resembles the roof of the old Birmingham

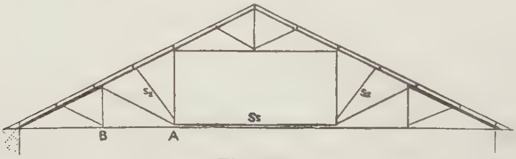


Fig. 368.

Theatre, and is recommended by Tredgold as a good truss for roofs of from 75 to 90 feet span.

In this case the triangular portion above the straining beam, being of considerable dimensions, is formed into a regular king-post truss.

The length of rafter between the queen post and princess being so great as to require support, this is afforded by means of a second strut, S_2.

In this roof the straining sill, SS, was keyed and bolted to the tie beam, and the tie beam was scarfed between A and B.

The scantlings adapted for the trusses shown in Figs. 364-368 are given at page 199.

Fig. 369 shows one of the principal trusses of the old roof of Exeter Hall.

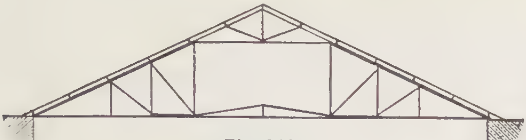


Fig. 369.

This truss is of 76 feet span, and includes a second set of princesses.

In other respects it is similar to the roof last mentioned, except that the straining sill is trussed as described at page 190.

The scantlings of this roof were as follows :—

	Inches.		Inches.
Tie beam	14½ × 7½	Struts	7½ × 7½
Principal rafters, long	8½ × 7½	Apex, king posts (oak)	6 × 7½
Principal rafters, short	14 × 7½	Apex, struts	6 × 7½
These extended only as far as the head of the queen post.		Straining sill	7½ × 7½
		Common rafters	5 × 2¼
Straining or collar beam	14 × 7½	Hip rafters	10 × 2½
Queen posts (oak)	8½ × 7½	Ridge piece	8 × 3½
Princesses	12 × 4½	Pole plates	12 × 4
do. outer set	10 × 4½	Wall plates	13½ × 6

Fig. 370 shows a similar form of roof, but with the apex re-

Fig. 370.

moved, and a lead flat substituted, the central portion, which carries the flat, being strengthened by the introduction of a king post and cross bracing.

Roofs composed of Wood and Iron for Spans of more than 40 Feet.—As already stated in Chap. X., the chief use of steel or iron in composite roofs is as a substitute for the wooden posts or suspending pieces which uphold the tie beam.

Cast iron is also used, in the form of shoes, heads, etc., for receiving and connecting the members of the truss.

It is not considered worth while to give any illustrations of composite roofs of wide span, as they are similar in principle to those illustrated in Chap. X., and have not been much used since the introduction of iron roofs.

PARTS OF A QUEEN-POST ROOF.

The parts common to all ordinary roofs, such as tie beams, rafters, wall plates, purlins, ridges, gutters, etc., have already been considered in Chap. X., and it remains only to give a description of those peculiar to queen-post roofs.

Queen Posts.—These have, between them, to carry about $\frac{2}{3}$ the weight of the tie beam, together with that of the ceiling, if any, suspended therefrom, and they frequently have to support additional loads brought upon the tie beam by the occupation of the space between the queen posts as a garret.

The heads of the queen posts are kept apart by a "straining beam," SB (Fig. 364), and the feet are tenoned into the tie beam and prevented from moving inwards by a "straining sill," SS.

The feet of the queen posts are sometimes secured by being housed on their inner sides into the tie beam, in which case the straining sill may be dispensed with.

Straining Beam.—The object of this beam has just been mentioned—its ends are supported by being housed and tenoned into the heads of the queen posts, additional security being generally afforded by cleats, C, nailed to the posts as shown.

When the straining beam is of considerable length it is sometimes supported in the centre by struts inclining inwards from the feet of the queen posts, as in Fig. 383, p. 197.

In that figure it is shown as supporting a lead flat, in which case it may with advantage be made thicker in the centre than at the ends, so as to strengthen the beam, and to give the lead a slight slope outwards.

Straining Sill.—This is generally merely a piece of scantling lying on the tie beam, and butting against the feet of the queen posts (Fig. 364, p. 187).

The straining sill is sometimes bolted and keyed to the tie beam in the manner explained under Built up Beams in Chap. VII.

It may, however, be arranged, as shown in Fig. 369 so as to form a truss and give support to the centre part of the tie beam.

In a roof with princess posts, straining sills may advantageously be introduced between the feet of the queens and princesses.

Binders, marked *Bi,* are shown in Fig. 383 framed in between the tie beams. This is sometimes a convenient arrangement for

stiffening the roof. It may also be adopted when the principals are widely spaced, in order to afford a shorter bearing for the ceiling joists.

Purlin Roofs.—When a long building is divided into rooms of moderate length by partition walls running across it, as shown in Fig. 371, the walls themselves play the part of the principals and carry the purlins, these latter supporting the rafters as usual.

If the purlins have to be of such a length that their scantling would be inconveniently large, they may with advantage be constructed in the form of trusses.

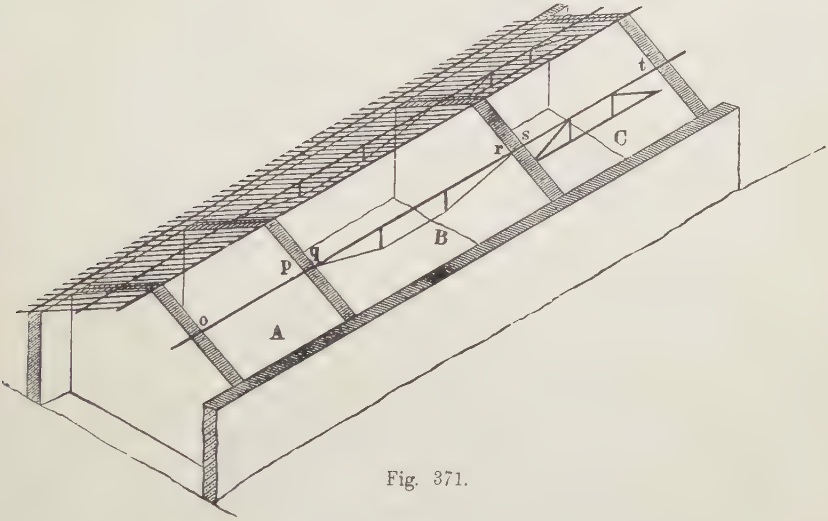


Fig. 371.

It will, however, be a question of economy whether it is more or less expensive to use trussed purlins than to introduce principals between the walls, so as to reduce the bearing of the purlins to such an extent that they may be formed with beams of ordinary scantling.

Fig. 371 shows a portion of a building of the description referred to above. The first space A, being of moderate length, is spanned by a purlin consisting of an ordinary beam *o p*. The next room B, being much longer, is crossed by a purlin, *q r*, trussed with iron rods as described on p. 149, while the roof on the third compartment, C, has a wooden purlin *s t* trussed in ordinary queen-post fashion.

The rafters resting upon the purlins are omitted on the near

side of the roof to avoid confusing the figure. The purlins should rest upon stone templates built into the walls; these are not shown in Fig. 371.

In some cases trussed purlins are used in connection with ordinary trussed principals; these latter being placed at a considerable distance apart.

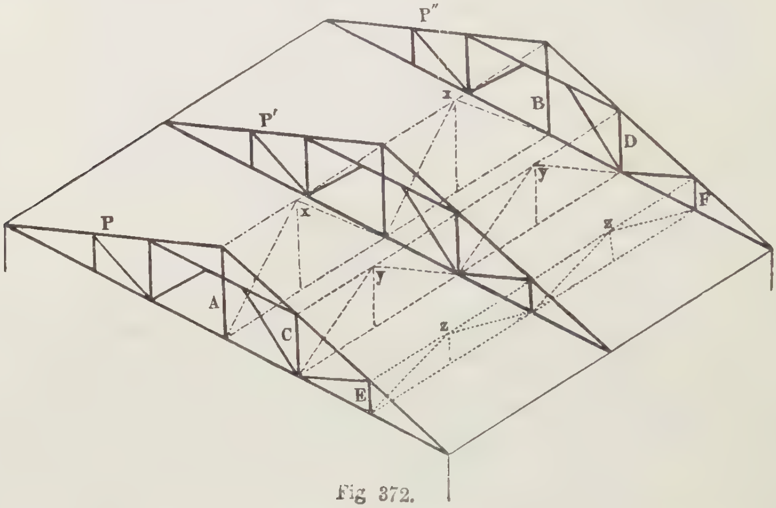


Fig 372.

For example, in the skeleton diagram Fig. 372, the principals P P′ P″, represented in thick lines, are 20 feet apart, and connected by trussed purlins (each dotted in a different manner), which are shown only on the near side of the roof; those on the farther side being omitted for the sake of clearness.

On these purlins may lie the common rafters, inclining downwards, parallel to the principal rafters, or intermediate principal rafters may be introduced, not forming part of a truss, but resting upon the purlins at *x y z*, and across the principal rafters horizontal common rafters may be placed.

This roof resembles that fixed at Christ's Hospital in 1834, the details of which will be found in Tredgold's Carpentry.

Horizontal Rafters.—Roofs are sometimes constructed with horizontal rafters extending across the principals, at right angles to them, as in Fig. 383. These are in fact purlins, except that they support the roof covering directly, having no rafters upon them.

This is a strong and cheap arrangement, and specially con-

venient when the roof covering is in large pieces, such as sheets of corrugated iron, which can be laid on the rafters without boarding.

When boards are required, they of course extend lengthways down the slope of the roof, and their edges are thus not so liable to be soaked with wet, in case of a leak, as they are when laid parallel to the ridge.

ROOFS OF VARIOUS SHAPES, AND THEIR PARTS.

Different names are given to roofs according to their form.

A **"Lean-to"**[1] roof has only one side or slope, which lies between two walls or other supports one higher than the other. See Fig. 373.

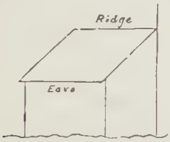


Fig. 373.

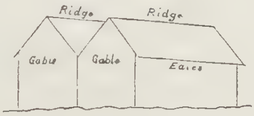


Fig. 374.

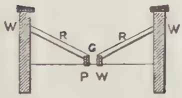


Fig. 375.

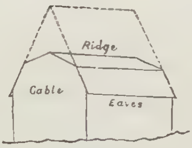


Fig. 376.

A **M Roof** consists of two ordinary triangular roofs side by side (Fig. 374).

A **V Roof** (shown in section, Fig. 375) has two slopes inclining inwards from side walls towards a gutter, which rests upon beams running along the centre of the building, and supported by the party walls PW.

A **Flat-topped Roof** is one in which the apex of the triangle is cut off flat, as in Fig. 383.

A **Curb or Mansard Roof** is one in which the apex of a high triangle is cut off and replaced by a flatter summit, as in Fig. 376, and Fig. 385, p. 198.

A **Conical Roof** is shaped like a cone.

An **Ogee Roof** has sides of which the lower portions are

[1] Sc. *To-fall.*

convex outwards and the upper portion concave, thus forming curves resembling that after which they are named. These two last descriptions are seldom required, and will not be further noticed.

The Ridge is the line formed by the meeting of the slopes of a roof at the summit.

The Eaves are the lower edges of the slopes, which rest upon the walls or project over them.

A Gable is formed when the end wall of a building is carried up so as to terminate the roof, as in Fig. 374.

A Hipped Roof[1] is sloped back at the ends as in Fig. 377. These terminating slopes are called the "hipped ends."

Hips[2] are the salient angles formed by the intersection of the sides and ends.

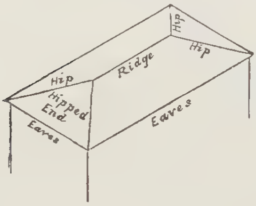


Fig. 377.

Valleys are the intersections similarly formed in re-entering angles (see VR VR, Fig. 378).

A Pavilion Roof is hipped uniformly at both ends, as shown in Fig 377.

Construction of Hipped Roofs.—If a roof terminates in gables, only ordinary principals are required in its construction, but if it is cut into by another roof or is hipped back at the ends special arrangements have to be made for the valleys and hips.

When a simple couple roof is "hipped," deep and narrow "*hip rafters*"[3] HR, Fig. 378, are carried from the end of the ridge to the angles of the end of the building, and short rafters, called "*jack rafters,*" *jr*, are cut to fit in between the hip rafters and the wall plates.

The same course is followed in the valley caused by the intersection of two roofs, "*valley rafters*" or *valley pieces* being introduced, as at VR VR in Fig. 378.

In framed roofs the jack rafters fit in between the hip rafters and the wall plates, or between the valley pieces and the ridges.

Fig. 378 is the plan, and Fig. 379 a sectional elevation, of a collar-tie roof covering a building of irregular form.

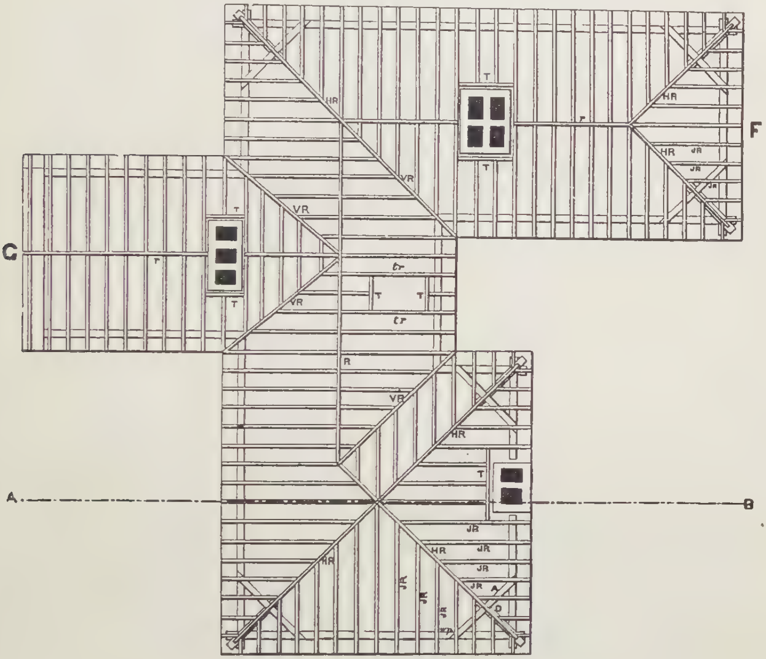
In the former figures, HR HR are the hip rafters, VR VR the valley rafters, DD the dragon pieces in the angles (see p.196), TT the trimmers carrying the rafters round openings left in the roof for chimneys, skylights, etc.

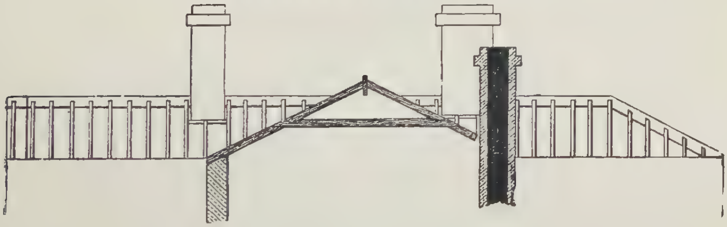
[1] Sc. *Piend roof.* [2] Sc. *Piends.* [3] Sc. *Piend rafters.*

Fig. 379 shows in section the collar-tie roof trimmed to clear the chimney, and in elevation the gable end G, and the end hipped back at F.

Fig. 378. Scale, $\frac{1}{10}$ inch = 1 foot.

Plan.





Sectional Elevation on A B

Fig. 379.

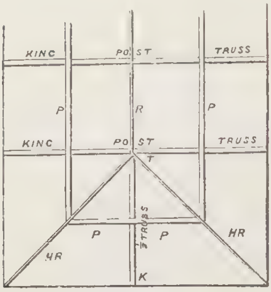


Fig. 380.

In a larger roof, such for instance as requires king-post trusses with purlins, as in Fig. 380, the length of the purlin, PP, on the hipped end would be too great to be left without support; in such a case a half king-post truss may be introduced at KT.

Similarly in a queen-post roof half principals are placed abutting against the queen posts of the first main truss, and at right angles to it.

In larger roofs flat-topped trusses must be introduced at intervals in the hipped ends to carry the rafters.

Framed Angle.—In a construction such as that described above, the hip rafter being very long and heavy requires to be well supported at its lower end, or it would thrust out the corner of the building; moreover the angle requires to be tied together.

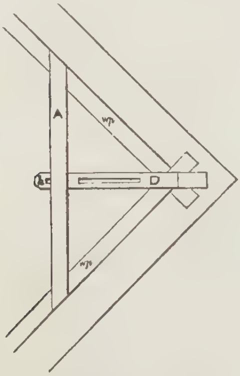


Fig. 381.

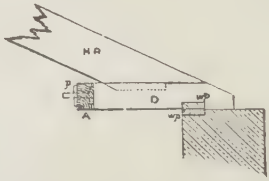


Fig. 382.

These objects are fulfilled by the arrangements shown in Figs. 381, 382. The foot of the hip rafter is tenoned into a mortise in the *dragon beam*[1] D, one end of which is notched into the wall plate *wp*, while the other is furnished with a strong tusk tenon which passes through a hole in the *angle brace* A.

After the hip rafter is fixed it is tightened up by driving a pin into the hole *h*.

Trimming.[2]—Wherever rafters come across any obstacle, such as a chimney, they must be trimmed in the same way as described in Chap. VI. for floor joists. Thus in Fig. 378 the rafters *tr tr*

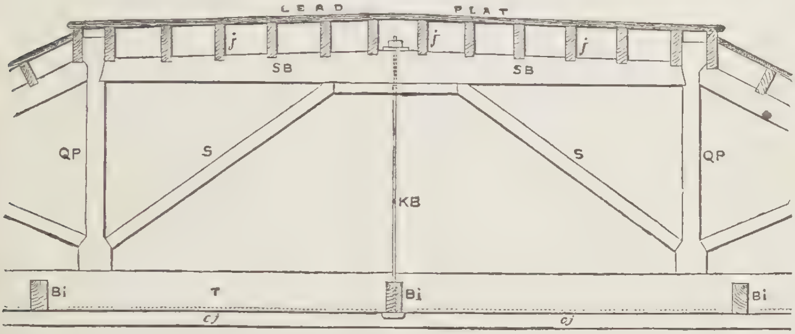
[1] Or dragging-tie. [2] Sc. *Bridling*.

would be made thicker than the others, and a trimmer, T, framed in between them. The rafters are similarly trimmed in order to leave openings for skylights, etc.

The roof in Fig. 209, p. 84, is trimmed to clear the chimney; the trimmer is shown in section at T.

The trimmers are often placed vertically, and sometimes supported in the centre by corbels protruding from the chimney.

Flat-topped Roofs.—Fig. 383 shows a method of forming a very nearly flat top to a queen-post roof.



Scale, ¼ inch to 1 foot.
Fig. 383.

The straining beam, SB, is made slightly thicker in the centre, so as to raise the joists, *jjj*, supporting the lead flat, sufficiently to throw off the wet. The rolls for the lead are not shown (see Chap. XIV.)

Sometimes rafters at a very flat slope are introduced above an ordinary straining beam to carry the joists.

As a considerable weight comes upon the straining beam, it receives additional support from two struts branching inwards from the feet of the queen posts, and kept asunder by a small straining piece. Fig. 383 shows also binders framed in between the tie beams, as described at p. 190.

Mansard or Curb Roofs were originally introduced in the days of very steep roofs, with a view to diminish their excessive height by cutting of the apex and substituting for it a summit of flatter slope.

This form of roof is condemned by Tredgold as being ungraceful in form, causing loss of room as compared with the original roof of high pitch, and further on account of the difficulty of freeing the gutters from snow. It is, moreover, a dangerous structure on account of its inflammability.

It is, however, much in use at the present time, as it affords an

economical attic story, and is considered by many to be more picturesque than the flatter roofs, while it is certainly much cheaper and less exposed than those of high pitch.

There are several ways of describing the outline of a Mansard roof.[1] Fig. 384 shows Belidor's method,[2] which is the one most usually adopted. It consists in dividing the semicircle, described on the span 0 5, into five equal parts at the points 1, 2, 3, 4, 5; the highest point r is then marked, lines joining 0 1 and 4 5 form the sides of the true roof, while 1 r and r 4 give those of the false roof or summit.

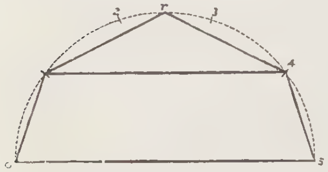


Fig. 384.

Fig. 385 shows an ordinary form of Mansard roof.

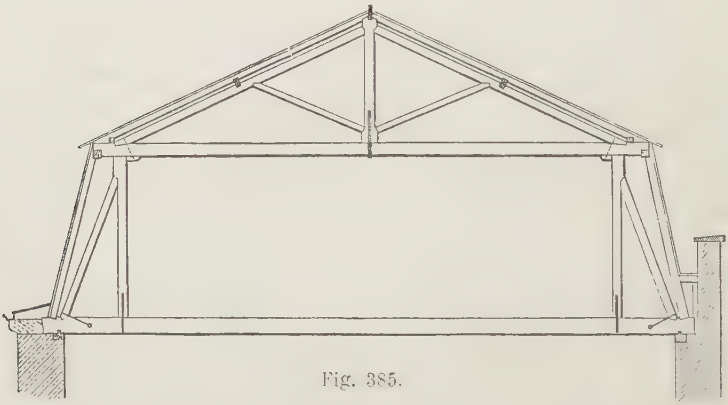


Fig. 385.

Those trusses that come immediately over a partition may be much strengthened if connected with it by prolonging the king post downwards so as to form the centre post of the partition (see Chap. VIII.)

Tredgold's Tables of Scantling for Roofs 30 to 60 feet span.—The following tables give the sizes of timber for roofs of from 30 to 60 feet span.[3]

Those for king-post roofs adapted for spans of from 20 to 30 feet are given in Chap. X.

[1] Theoretically the beams should be in equilibrium, and support each other without fastenings: to do this they should be arranged in the form they would assume if loosely connected at the ends, and then inverted and allowed to hang in a catenary curve.

[2] From Newland's *Carpenter's and Joiner's Assistant.*

[3] The table of queen-post roofs from 32 to 46 feet span is repeated from p. 178 for the sake of comparison.

QUEEN-POST ROOFS, such as in Fig. 364.—TABLES of SCANTLINGS of TIMBER for different Spans, from 30 to 46 feet.

Span.	Tie beam, T.	Queen Post, QP.	Principal Rafters, PR.	Straining Beam, SB.	Struts, S.	Purlins, P.	Common Rafters, CR.
32 ft.	10 by 4½	4½ by 4	5 by 4½	6¾ by 4½	3¾ by 2¼	8 by 4¾	3½ by 2
34 ,,	10 ,, 5	5 ,, 3½	5 ,, 5	6¾ ,, 5	4 ,, 2½	8¼ ,, 5	3¾ ,, 2
36 ,,	10½ ,, 5	5 ,, 4	5¾ ,, 5	7 ,, 5	4¼ ,, 2½	8½ ,, 5	4 ,, 2
38 ,,	10 ,, 6	6 ,, 3¾	6 ,, 6	7¼ ,, 6	4½ ,, 2½	8½ ,, 5	4 ,, 2
40 ,,	11 ,, 6	6 ,, 4	6 ,, 6	8 ,, 6	4½ ,, 2½	8¾ ,, 5	4¼ ,, 2
42 ,,	11½ ,, 6	6 ,, 4½	6¼ ,, 6	8¼ ,, 6	4½ ,, 2¾	8¾ ,, 5¼	4½ ,, 2
44 ,,	12 ,, 6	6 ,, 5	6½ ,, 6	8½ ,, 6	4½ ,, 3	9 ,, 5	4¾ ,, 2
46 ,,	12½ ,, 6	6 ,, 5½	7 ,, 6	9 ,, 6	4¾ ,, 3	9 ,, 5½	5 ,, 2

QUEEN AND PRINCESSES ROOFS, such as in Fig. 367.—TABLE of SCANTLINGS of TIMBER for different Spans, from 46 to 60 feet.

Span.	Tie beam, T.	Queen Post, QP.	Princesses PP.	Principal Rafters, PR.	Straining Beam, SB.	Struts, S.	Purlins, P.	Common Rafters, CR.
48 ft.	11½ by 6	6 by 5¾	6 by 2¼	7½ by 6	8¼ by 6	4½ by 2¾	8½ by 5	4 by 2
50 ,,	12 ,, 6	6 ,, 6¼	6 ,, 2½	8½ ,, 6	8½ ,, 6	4½ ,, 2¾	8¾ ,, 5	4¼ ,, 2
52 ,,	12 ,, 6½	6 ,, 6¾	6 ,, 2¾	9¼ ,, 6	8¾ ,, 6	4¾ ,, 2¾	8¾ ,, 5¼	4¼ ,, 2
54 ,,	12 ,, 7	7 ,, 6¼	7 ,, 2¼	8¼ ,, 7	9 ,, 6	4¾ ,, 2¾	8¾ ,, 5¼	4½ ,, 2
56 ,,	12 ,, 8	7 ,, 6¾	7 ,, 2½	8½ ,, 7	9¼ ,, 6	5 ,, 2¾	8¾ ,, 5¼	4½ ,, 2
58 ,,	12 ,, 8½	7 ,, 7¼	7 ,, 2¾	8¾ ,, 7	9½ ,, 7	5 ,, 2¾	9 ,, 5¼	4¾ ,, 2
60 ,,	12 ,, 9	7½ ,, 7	7 ,, 3	9 ,, 7	10 ,, 7	5 ,, 3	9 ,, 5½	4¾ ,, 2

QUEEN AND PRINCESSES ROOFS, with trussed apex, such as in Fig. 368.—TABLE of SCANTLINGS of TIMBER for different Spans, from 60 to 90 feet.

Span.	Tie beam, T.	Queen Post, QP.	Princesses, PP.	Principal Rafters, PR.	Straining Beam, SB.	King Post, KP.	Struts, S.	Purlins, P.	Common Rafters, CR.
65 ft.	15 by 10½	8 by 7	5 by 3	8 by 7½	10½ by 8	5 by 3	5 by 3½	8¼ by 5	4 by 2
70 ,,	15 ,, 11¾	9 ,, 6½	5 ,, 3½	9 ,, 7	10½ ,, 9	5 ,, 3½	5 ,, 4	8½ ,, 5	4¼ ,, 2
75 ,,	15 ,, 13¾	9 ,, 7½	5 ,, 4	9 ,, 8	11¼ ,, 9	5 ,, 4	5 ,, 4½	8¾ ,, 5	4½ ,, 2
80 ,,	16 ,, 13	9 ,, 9	6 ,, 4	10½ ,, 9	12 ,, 9	6 ,, 4	6 ,, 3½	8¾ ,, 5¼	4½ ,, 2
85 ,,	16 ,, 13½	9½ ,, 9	6 ,, 4½	12 ,, 9	12¾ ,, 9	6 ,, 4½	6 ,, 4	9 ,, 5¼	4¾ ,, 2
90 ,,	16 ,, 14	10 ,, 9¾	6 ,, 4½	13¼ ,, 10	13 ,, 10	6 ,, 4½	6 ,, 4	9 ,, 5½	5 ,, 2

N.B.—In these Tables the pitch of the roof is supposed to be about 27°; the trusses 10 feet apart. The covering slates and the timber to be good Memel or Riga fir. Inferior timber will require to be of larger dimensions. The scantlings for the tie beams may be considerably reduced when they do not carry ceiling joists. See Seddon's Tables, p. 179.

TREDGOLD'S RULES FOR SCANTLING OF ROOF TIMBERS.

The following rules laid down by Tredgold will be useful to those who are unable to find the direction and amount of the stresses on various parts of a roof; and thus by a more accurate method to arrive at the sizes necessary for the different members.

The student should observe that though these look like complicated formulæ, they are very simple, being merely letters substituted for words, as in Hurst's Pocket-book, and they require nothing but ordinary arithmetic for their application.

B = Breadth of piece in inches. D = Depth of piece in inches. A = Area of section of piece in inches = B × D. L = Length of piece in feet. S = Span of roof in feet.

Tie Beam.—u = Length of longest unsupported part in feet.

When the tie beam has to support a ceiling only.

$$D = \frac{u}{\sqrt[3]{B}} \times 1{\cdot}47 \text{ for fir, or } \times 1{\cdot}52 \text{ for oak.}$$

When there are rooms above, the tie beam must be calculated as a girder (see Chap. VI. p. 142).

Ceiling Joists 12 inches from centre to centre.

$$D = \frac{L}{\sqrt[3]{B}} \times 0{\cdot}64 \text{ for fir, or } \times 0{\cdot}67 \text{ for oak.}$$

King Post.—$A = L \times S \times 0{\cdot}12$ for fir, or $\times 0{\cdot}13$ for oak.

King Bolt.—Diameter in inches $= \sqrt{S} \times 0{\cdot}2$.

Queen Post.—t = length in feet of part of tie-beam suspended by the queen post.

$$A = L \times t \times 0{\cdot}27 \text{ for fir, or } \times 0{\cdot}32 \text{ for oak.}$$

Queen Bolt.—Diameter in inches $= \sqrt{t} \times 0{\cdot}29$.

Struts and Braces.—r = length of part of principal rafter supported by the strut, in feet.

$$D = \sqrt{L \times \sqrt{r}} \times 0{\cdot}8 \text{ for fir.}$$

$$B = \tfrac{6}{10} D.$$

Principal Rafters.—Supported by struts over which the purlins rest.

In King-post roof.—$D = \frac{L^2 S}{B^3} \times {\cdot}096$ for fir.

In Queen-post roof.—$D = \frac{L^2 S}{B^3} \times 0{\cdot}155$ for fir.

The thickness is generally the same as that of the tie beam and king or queen posts

Purlins.—C = distance in feet that the purlins are apart.

$$D = \sqrt[4]{L^3 \times C} \times 1{\cdot}0 \text{ for fir, or } 1{\cdot}04 \text{ for oak.}$$

$$B = \tfrac{6}{10} D$$

Common Rafters.—$D = \dfrac{L}{\sqrt[3]{B}} \times 0{\cdot}72$ for fir, or $0{\cdot}74$ for oak.

Straining Beam.—In the best form for strength the depth is to breadth as 10 to 7.

$$D = \sqrt{L \times \sqrt{S}} \times 0{\cdot}9 \text{ for fir.}$$
$$B = \tfrac{7}{10} D.$$

BEST FORMS OF ROOF FOR DIFFERENT SPANS.

The best form of roof truss or principal to be used for a given span is determined by the following considerations:—

1. The parts of the truss between the points of support should not be so long as to have any tendency to bend under the thrust; therefore the length of the parts under compression should not exceed twenty times their smallest dimension. This will be explained in Part IV.

2. The distance apart of the purlins should not be so great as to necessitate the use of either purlins or rafters too large for convenience or economy.

3. The tie beam should be supported at such small intervals that it need not be too large for economy or convenience.

It has been found by experience that these objects can be attained by limiting the distance between the points of support on the principal rafter to 8 feet.

In determining the form of truss for any given span, it is therefore necessary first to decide the pitch, then roughly to draw the principal rafters in position, ascertain their length, divide them into portions 8 feet long, and place a strut under each point of division.

By this it will be seen that a king-post truss is adapted for roofs with principal rafters 16 feet long, *i.e.* those having a span of 30 feet. A queen-post truss would be adapted to a roof with principal rafters 24 feet long, that is of about 45 feet span.

For greater spans with longer principal rafters, roofs such as that in Figs. 367 to 370 must be used.

CHAPTER XII.

ROOF COVERINGS.

General Remarks.—Roofs are covered with different materials according to the locality, the climate, and the nature and importance of the building

As a rule, the smaller the pieces in which the covering is put on, the heavier will it be, and the more difficult to keep watertight, as it will contain a greater number of openings or of joints.

Substances which conduct heat very slowly, such as slate, make better coverings than the metals; the former preserve a equable temperature, while the latter conduct the heat in summer, and the cold in winter, to the interior of the building.

Pitch of Roofs.—The pitch, or inclination of the sides of a roof, is determined chiefly by the nature of the covering.

Thus thatch, which would easily allow wet to penetrate it, must be laid at a steep angle, so as to throw the water off at once; whilst, on the other hand, hard and impervious slates may be laid at a much smaller angle, and sheets of metal may be nearly flat.

The pitch is, moreover, varied greatly to suit different styles of architecture, and also according to climate. Some writers have gone so far as to prescribe an exact pitch for every variation in latitude.

The following remarks by the late Professor Robison are of a more practical character:—

" A high-pitched roof will undoubtedly shoot off the rains and snows better than one of lower pitch; the wind will not so easily blow the dripping rain in between the slates, nor will it have so much power to strip them off;" and further—" A high-pitched roof will exert a smaller strain upon the walls, both because its strain is less horizontal, and because it will admit of lighter covering; but it is more expensive, because there is more of it,—it requires a greater size of timbers to make it equally strong, and it exposes a greater surface to the wind."

The pitch of a roof is expressed either by the angle which its sides make with the horizon, or by the proportion which its height in the centre bears to the span.

Thus the roof shown in Fig. 364, p. 187, may be said to have a pitch of $26\frac{1}{2}$ degrees or $\frac{1}{4}$.

The subjoined table, taken chiefly from Tredgold, gives the inclination for roofs covered in different ways. The weights of various coverings are also given, but these will vary considerably according to the quality and thickness of the material used.

TABLE.

Kind of Covering.	Inclination of sides of Roof to Horizon.	Height of Roof in parts of Span.	Weight on a square (*i.e.* 100 square feet) of roofing in lbs.
Asphalted Felt . .	3° 50′	$\frac{1}{30}$	30 to 40
Copper	3° 50′	$\frac{1}{30}$	80 to 120
Corrugated Iron, 16 BWG[1]	18° to 20°	$\frac{1}{6}$	350
Sheet Iron, 16 BWG .	18° to 20°	$\frac{1}{6}$	250
Lead	3° 50′	$\frac{1}{30}$	550 to 850
Slates (large) . . .	22° 0′	$\frac{1}{5}$	900 to 1100
,, (ordinary) . .	26° 30′	$\frac{1}{4}$	550 to 800
,, (small) . .	33° 0′	$\frac{1}{3}$	450 to 650
Slabs of Stone . .	39° 0′	$\frac{2}{7}$	2380
Thatch (Straw) . .	45° 0′	$\frac{1}{2}$	650
Tiles (Plain)[2] . .	$52\frac{1}{2}$°	$\frac{4}{3}$	1800
,, (Pan) . . .	24° 0′	$\frac{2}{9}$	1200
,, (Taylor's Patent) .	30° 0′	$\frac{1}{3}$	830
Zinc ($\frac{1}{32}$ in. thick) . .	4° 0′	$\frac{1}{20}$	150
Boarding ($\frac{3}{4}$ thick) . .	26° 30′	$\frac{1}{4}$	250
,, 1 ,, . .	26° 30′	$\frac{1}{4}$	350

N.B.—The additional pressures to be taken into account in practice are the following:—

Pressure of wind . . . . 2500 to 5000 lbs. per square of 100 feet.
do. of snow, in this country 500 lbs. per square.

Slating.—The particulars connected with the different methods of laying slates, also slate ridges and hips, are entered upon in Chap. XIII., and need not here be further considered.

Tiles of burnt clay are made in several different forms, a few of the more important of which will be described.

They are heavy and rather apt to absorb moisture, and to communicate it to the laths and rafters of the roof, thus rendering the latter liable to decay.

[1] BWG stands for Birmingham wire-gauge—a measure of thickness (see Part III.)

[2] Plain tiles are used on roofs of any pitch from 30° to 60°.

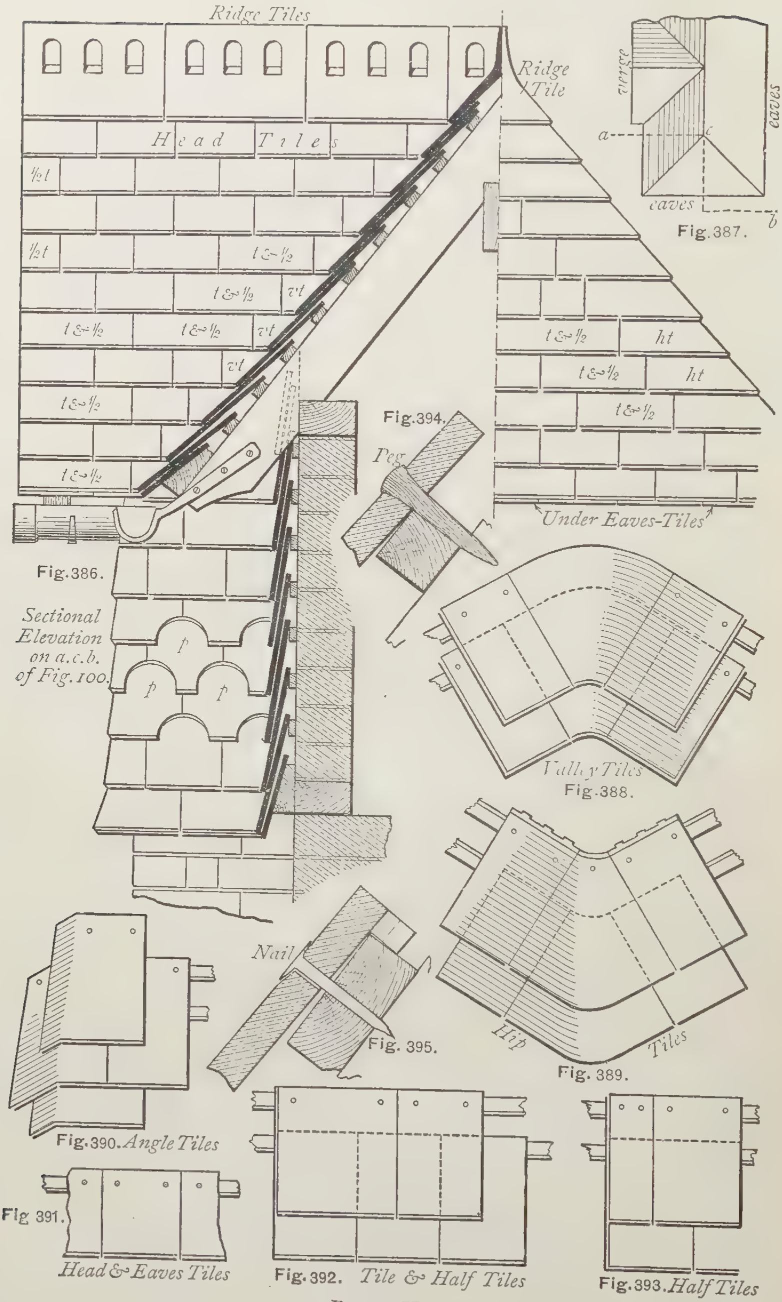

Ridge Tiles
Ridge Tile
Head Tiles
½t
t & ½
vt
ht
Fig.387.
verge
eaves
a
c
b
Fig.394.
Peg
Under Eaves-Tiles
Fig.386.
Sectional Elevation on a.c.b. of Fig.100.
p
Valley Tiles
Fig.388.
Nail
Fig. 395.
Hip Tiles
Fig. 389.
Fig.390. Angle Tiles
Fig 391.
Head & Eaves Tiles
Fig. 392. Tile & Half Tiles
Fig. 393. Half Tiles

PLATE II.

PLAIN TILES are slabs of burnt clay, either rectangular or in various patterns, as at *p, p*, Fig. 386, Pl. II., generally about $10\frac{1}{2}$ inches long, $6\frac{1}{2}$ inches wide, and about $\frac{1}{2}$ inch thick. They are slightly curved in their length to make them lie close.

They are laid on battens $1\frac{1}{2}$ inch × $\frac{1}{2}$ inch, or on laths of oak or fir, being hung from them by wooden pins driven through holes near the upper edge of the tiles. Sometimes the tiles are hung by projecting nibs, of which there are generally two or three upon their upper edges. Sometimes only every third or even only every tenth course is nailed.

The arrangement of the tiles is similar to that of slates—the tail of each rests upon the tile below for a length of about 6 inches, the gauge being 4 inches (often $3\frac{1}{2}$ inches) and the lap over the head of the tile next but one below about 3 inches.

WEATHER TILING.[1]—Plain tiles are often used vertically to protect walling. Battens are nailed upon the wall, and the tiles hung upon them in somewhat the same manner as for roofs,—each tile being bedded in mortar so as to make the covering warm and weather-tight.

Plate II. shows in Figs. 386, 387, part of a plain tiled roof and of a wall with hanging tiles. Figs. 388-393 show various forms of tiles which are necessary to make good work, as shown in Fig. 386.

Fig. 394 shows the method of securing a tile by a pin which should be preferably of oak or otherwise of heart of Memel cut with a knife out of any dry stuff. Fig. 395 shows a tile secured by a nail which should be of copper or of malleable iron.

Ridges may be as shown in Fig. 386. Sometimes the ridge tiles have longitudinal grooves along their upper edges, into which detached ornamental "fleurs" are fitted. Sometimes they have ventilating openings in them.

Torching and Pointing.—The tiles after being laid should be *torched or tiered*, that is pointed from the inside with hair mortar. The *Verges* (see Fig. 387) should be pointed in cement, and the ridges, finials, etc., set in cement. In very exposed places each tile may be bedded in hydraulic mortar or cement upon those below it.

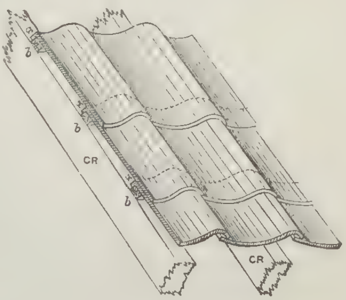


Fig. 396.

PAN TILES form a covering not so warm as one of plain tiles, and liable to injury from gusts of wind.

The tiles are about 14 inches long by 9 inches straight across the width. Each is hung on to the laths or battens, *b b*, by a nib which projects from the upper edge of the back of the tile,—

[1] Or *Hanging Tiling.*

shown in section at $x\ x\ x$. It should be remarked that this projection is not continuous throughout the width of the tile, but is only about one inch wide.

The tiles have a lap of 3 inches to 4 inches, and the joints on the under sides are pointed with hair mortar.

Pan tiles are well adapted for roofing over workshops where large furnaces are used, as they withstand the heat, and the interstices between them afford plenty of ventilation.

Half round or concave tiles set in mortar, and nailed to the woodwork, are used for the ridges, hips, and valleys. For common work sometimes the tiles themselves are used—the smaller curved portion being cut off,—but special tiles are generally made for the purpose.

In exposed situations, and where much ventilation is not required, the tiles are bedded on each other in mortar, and the space between the ridge tiles and those in the ridge courses at the top of the slopes are filled in with pieces of flat tiles bedded in mortar.

Glass Tiles of this form are made, and may be introduced among the others where light is required. *Double Roll Tiles* are similar to the above, but have a double wave in their width. *Corrugated Tiles* are similar in general form to pan tiles, but they are bent into several narrow curved or sometimes angular corrugations, instead of only two broad ones.

Italian Tiles are shown in section and elevation in Figs. 397, 398, from which the construction of the tiles is obvious.

These tiles present a handsome appearance, which leads to their

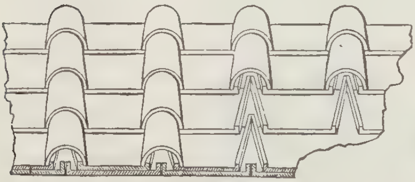


Fig. 397. *Elevation.*

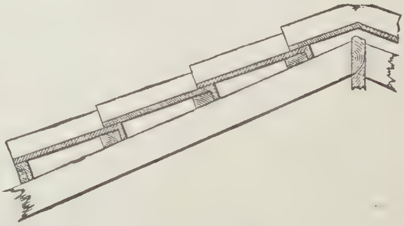


Fig. 398. *Section.*

use in some cases; but they are not well adapted to the British climate, as they cause the snow to lodge, and, when it thaws, the water frequently gets through the roof.

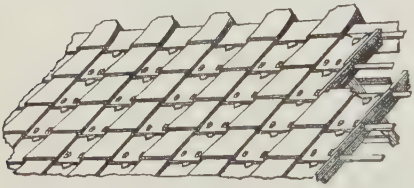


Fig. 399.

Fig. 400.

Taylor's Patent Tiling is somewhat similar in principle to the Italian tiling just described.

In this case, however, the upper or *capping tiles* are exactly like the lower or *channel tiles*, so that every tile can be used in either position.

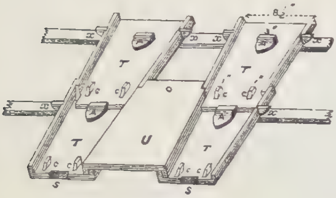


Fig. 401.

Fig. 399 shows the general appearance of this kind of tiling, which is very picturesque.

Fig. 400 gives an upper and lower view of the tiles.

Fig. 401 shows a few channel tiles, T T, with one capping tile, U, in position.

The tiles are hung on battens $2\frac{1}{4}$ inches wide and 1 inch thick, laid to about a 10-inch gauge. The channel tiles are first laid in rows along the slope of the roof from eaves to ridge; the narrow end of each tile is pushed into the wide end of the one below until the splay, *s*, fits firmly into the undercut in the shield, A, of the lower tile.

There are notches in the sides of the tiles, as shown at *n n* Fig. 400; each channel tile is secured by wedge-shaped nails[1] driven in alongside, so as to hold the tile down by these notches as at *x x*.

After the channel tiles are all fixed, the capping tiles are put on. These tiles are turned over, and so placed as to cover the intervals between the channel tiles. They are pushed downwards until the little blocks or cogs, *c c*, rest upon the nail-heads, *x x*, which secure the channel tiles below.

The under side of the corners of the joints between the tiles is pointed with cement mortar.

Foster's Lock Wing Roofing Tiles are illustrated in Fig. 402,[2] which explains itself. It is claimed for these tiles that they are cheaper than the

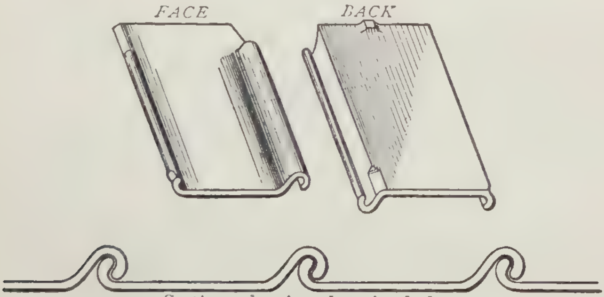


Fig. 402.

commonest tiles made, can be hung quickly and without skilled labour, require no pointing, and cannot be blown off the roof, as the stronger the pressure is underneath, the tighter the lock.

[1] Or side keys. [2] From the Patentee's Circulars.

Poole's Patent Bonding Roll Roofing Tiles are shewn in Fig. 403,[1] which requires no description.

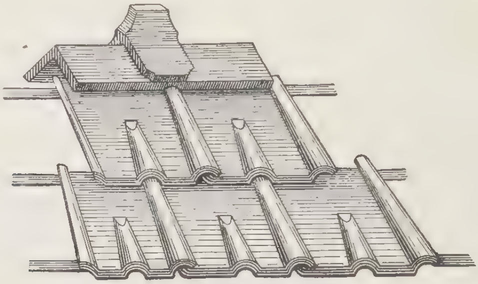


Fig. 403.

Thatch is made of wheaten straw[2] laid on laths nailed (8 inches apart) to rafters, frequently of a very rough kind. This covering keeps a building warm in winter and cool in summer, but it is very subject to destruction by fire or decay, and generally forms a refuge to insects and vermin.

The pitch should be 45°. If it is less the rain will not run off freely; if more, the straw slips down.

The thatch is sewn down on the lathing in small bundles, until it attains a thickness of from 12 to 16 inches over the roof generally, but it is sometimes thinned down to nothing, just at the eaves.

About $3\frac{1}{2}$ cwt. of wheat straw is required per square. It will last in England from fifteen to twenty years,—oat straw about eight years.

Wrought Iron plain sheets are sometimes used, the longitudinal joint down the slope being formed by bending the two edges of adjacent plates over a roll of wood.

Corrugated Iron plates are much used.[3] They are made in sheets varying in size from 6 feet × 2 feet to 8 feet × 3 feet, and in thickness from $\frac{1}{45}$ to $\frac{1}{16}$ inch, that is, from No. 24 to No. 16 Birmingham wire gauge. The sheets of medium thickness (for example, of No. 20 gauge with 5-inch flutes) require to be supported only at intervals of from 6 to 8 feet, and the roof may thus be cheapened by omitting the intervening purlins. Ordinary corrugated iron is so laid that the flutes run down parallel to the slope of the roof. The sheets overlap at the sides, and should be screwed at the top and bottom edges to the roof timbers. The screws should be on the ridges of the corrugations, so that all wet may at once be thrown off them.

Corrugated iron is sometimes laid with the flutes horizontal, so that the sheets span the interval between the principals, and all

[1] From the Patentee's Circulars.

[2] Reeds make the best thatched roofs, but the use of reeds for roofing has nearly died out.

[3] See Part iii., p. 290.

rafters and purlins can be dispensed with. In such a case the flutes should be of a peculiar angular shape,[1] so as to throw off the water.

Corrugated iron is often galvanised, but if the coating be once pierced it is soon destroyed by the voltaic action between the two metals; it is, therefore, better merely to paint the surface.

It is sometimes protected from atmospheric influences by an external covering of asphalted felt, which is made to adhere to it by means of a composition.

Corrugated iron is frequently used not merely as a covering, but to form the roof itself, the sheets being riveted together and bent into an arched form.

Sheet Lead is used for covering flat roofs, and also for many portions of ordinary roofs, such as the gutters and flashings; the different methods of laying it are described in Chap. XIV.

Lead is not adapted as a covering for pitched roofs, owing to its expansion and contraction, by virtue of which it will crawl down a roof. During a warm day it expands, the expansion being assisted downwards by the action of gravity; in the cool night it contracts, the contraction being diminished by the force of gravity acting downwards: the consequence is it contracts each night less than it expanded during the day, and in time gains a considerable distance.[2]

Copper is sometimes used in sheets weighing about 16 ounces per foot superficial. They should be laid on boards in the same manner as those of lead. The coating of oxide formed by the action of the air preserves the surface to a certain extent, but the first cost of this metal is so great as to prevent its being much used.

Zinc is laid as a roof covering in several different ways.

Its lightness, as compared with slates, tiles, or lead, enables it to be laid on roof-timbers of much smaller scantlings than those required for the coverings just mentioned.

The method of laying zinc in this country has been greatly improved through the exertions of the Vielle Montagne Zinc Company, from whose beautifully illustrated pamphlet[3] on the subject the figures and most of the information here given have been extracted.

There are several methods of laying zinc on roofs; in all of them the object should be to avoid soldered and rigid connection, and to arrange the joints so that they may be water-tight, but may still allow free play for contraction and expansion of the metal under changes of temperature.

[1] See Part III. p. 290.
[2] The lead on the moderately-inclined roof of Bristol Cathedral crawled down 18 inches in two years—Tyndall, *Heat as a Mode of Motion.*
[3] Published by their manufacturing agents, Messrs. F. Braby and Company.

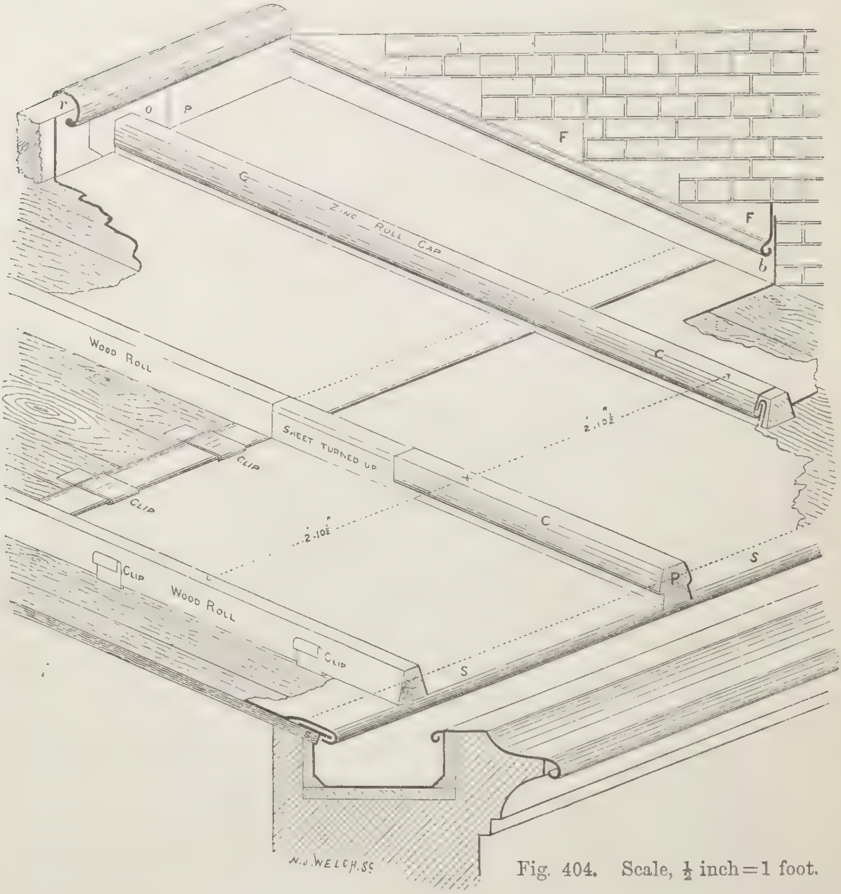


Fig. 404. Scale, ½ inch = 1 foot.

Zinc laid with plain Roll Caps on boarding.—Flat sheets of zinc from 7 to 10 feet long and 3 feet wide, are laid with wooden rolls on boarding very much in the same manner as lead.

Fig. 404 shows a portion of a roof covered in this manner. The sheets run lengthways down the slope of the roof, their side edges being turned up against the rolls, which are placed 2 feet 10½ inches apart from centre to centre.

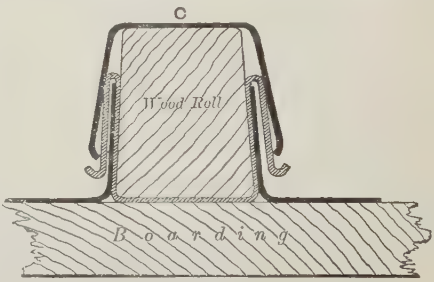


Fig. 405.

A section of one of these rolls, showing the method of securing the zinc, is shown on a larger scale in Fig. 405.

The scored portion of the section shows one of the zinc clips, which are strips about 2 inches wide, fixed about 3 feet apart along the roll. Being doubled over the upturned side edges of the sheets, the clips hold them down, without preventing their expansion and contraction under changes of temperature.

After the sheets are laid and secured by the clips, the rolls are covered by the cap C, also formed of sheet zinc, doubled down as shown. In very exposed situations these clips may be continued so as to turn up again over the sides of the cap C, and be secured at the top.

The cap is secured by "fork connections." These consist of pointed pieces of zinc 2 or 3 inches long by about an inch wide, one end of which is soldered to the inner surface of the cap on each side, the point being free. As the cap slides on to the roll, the points of these forks slip in under the hooked portion of the clip. They thus prevent the clip from flying off, without impeding its expansion and contraction in direction of its length.

Braby's Patent Saddle-piece and Stop-end.—The extreme ends of the roll caps may be covered with a piece soldered on, as shown at O and P; but this plan has been improved upon by merely spreading out the roll cap itself at O, forming what is called a saddle-piece, and dressing it up against the side of the ridge; and at the end, P, by turning the end of the cap over the end of the roll, and doubling the corners of the sides of the cap under the end—thus, in both cases, doing away with soldered joints, and allowing perfect play under expansion and contraction. There are other patented methods of effecting the same object, which cannot here be described.

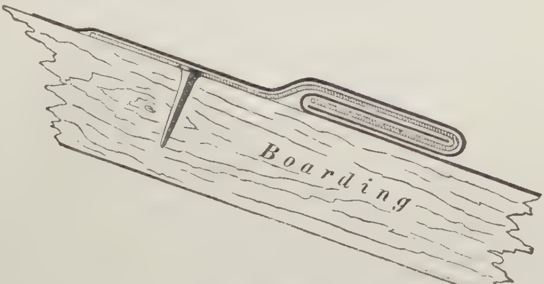


Fig. 406.

WELTED JOINTS.—The sheets having been fastened at the sides by means of the rolls as above described, it next becomes neces-

sary to make a connection between the lower edge of each sheet and the upper edge of the sheet next below it on the slope of the roof (Fig. 404).

This is done by means of the joint shown in section in Fig. 406 and called a *Welt* or *Fold* joint.

In this figure the hatched section is that of a "clip," or strip of zinc about 2 inches wide nailed to the boarding, and doubled in between the edges of the two sheets to be connected, which are shown in section by the black lines, so as to make a secure joint, and yet to give them plenty of play for expansion and contraction.

Welted joints are used only when the roof has a slope of $\frac{1}{7}$ or more; for flatter roofs drips are introduced.

The lower edges of the sheets nearest the eaves are strengthened where they project over the gutter, by being doubled back so as to form a bead; and further, by a strip of stout zinc (S in Fig. 404), nailed along the edge of the boarding over which the bead is formed.

The ridge is covered by a zinc roll cap turned over it, which latter is strengthened on the lower edges by their being bent round to form beads.

Drips.—Zinc may be fixed with rolls on boarding laid upon roofs of any pitch not less than about 1 in 15.

When, however, the slope of the roof is flatter than $\frac{1}{7}$, drips should be formed similar to that shown in Figs. 407, 408, at intervals of from 7 to 8 feet, that is at the end of each sheet.

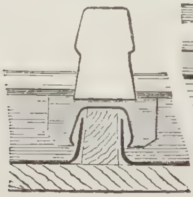


Fig. 407. *End Sectional Elevation.*

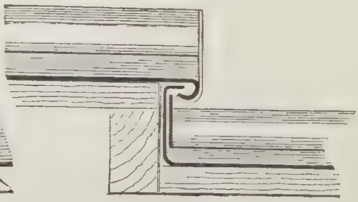


Fig. 408. *Side Sectional Elevation.*

The figures show the end elevation and the section of a drip joint over a roll.

The thick lines show the sections of the sheets, the ends of which, it will be noticed, are bent inwards, so that they may be able to expand and contract without danger of any water getting in behind the joint.

The stopped end of the roll cap on the upper level is bent over with the edge of the sheet.

Drips in flats should be $2\frac{1}{2}$ inches deep, and in gutters $1\frac{1}{2}$ inch deep.

Zinc laid with patent drawn Roll Cap.—Another form of roll patented by the Vielle Montagne Zinc Company is recommended as lasting longer than the simple form just described, and as being peculiarly suitable "for terraces or flats of warehouses where weights are stored, or where there is much walking about;" and, as regards appearance, for Mansard or high-pitched roofs.

The method of laying zinc with these rolls is somewhat similar to that with the ordinary rolls; but the loose zinc roll cap is done away with, the zinc being drawn tight over the roll by machinery.

Corrugated Zinc Roof.—When the zinc is required to be laid without boarding—which is, of course, a great saving—it must be strengthened by corrugations, *i.e.* by curved indentations or flutes formed along the sheet.

The ordinary corrugated zinc consists of flutes about $3\frac{1}{2}$ inches wide, lying close together.

It is laid in a similar way to corrugated iron (p. 208), the purlins being placed about 2 feet 6 inches apart.

Italian Corrugated Zinc Roof.—In this form of zinc the corrugations are spaced more widely, being 1 foot 3 inches apart.

In Fig. 409 one sheet is shown in section by the thick black line, the ends of the adjacent sheets being scored in section.

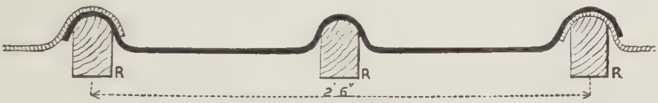


Fig. 409.

The zinc may be laid upon rafters, so spaced and shaped as to fit into the corrugations (Fig. 409), but for the sake of durability it is better to lay it upon boarding.

The sheets are secured to them, either by patent holding down clips shaped so as to allow of the expansion and contraction of the sheets, or by patent sliding studs. Both methods are fully described in Messrs. Braby's pamphlet.

Fig. 409 shows in section a portion of a roof covered with Italian corrugated zinc. The zinc rolls or rafters are 1 foot 3 inches apart, and are supported upon purlins, which in large roofs may be 10 feet apart.

The depth of the rolls when they act as rafters, and are laid

upon purlins about 7 feet apart, is about 3 inches; but when laid upon boarding they are only 2 inches deep.

Thickness of Zinc for roofing.—The gauges[1] recommended by the Vielle Montagne Company are Nos. 14, 15, and 16 zinc gauge (see Part III.) for the roof covering.

"No. 14 to be used only where it is necessary to exercise the greatest possible saving in the first cost."

No. 15 or 16 for gutters.

Nos. 14 and 15 for flats.

Nos. 13 and 14 are frequently used for roofing, where economy is an object.

It must be noted that these are the numbers of the Vielle Montagne Company's *zinc* gauge, not of the ordinary Birmingham wire gauge.

Zinc Flashings are very similar to those of lead described in Chap. XIV. An illustration of one is shown at F in Fig. 404.

The edge of the sheet is generally turned up about 6 inches against the wall, and the apron over it is finished and stiffened by being bent round to form a bead *b* as shown.

The ridge roll is covered with zinc in nearly the same manner as with lead, except that the zinc is not worked so much into the angles under the roll. It is secured by forks, similar to those described in page 211.

ZINC GUTTERS.—*Valley Gutters* are formed in somewhat the same manner as those of lead.

For roofs laid with wood rolls the wooden trough is lined with sheet zinc,—the sides of which are turned up, and the upper edges bent inwards under the bead formed by the lower edge of the sheet at the eaves.

Where Italian corrugated zinc is used the sides of the zinc lining to the gutters are turned up, and the edges bent over the thickness of the wood sides of the trough.

The minimum fall for such gutters should be $\frac{1}{40}$.

Zinc Tiles, generally of diamond or shield shape, are sometimes used for roof coverings, each being hung from a hook fixed upon battens or boarding, and passing through a hole near the top of the tile.

Zinc Eaves Gutters[2] are made of various forms, very similar to those of cast-iron, and are fixed in the same positions.

They soon perish, and are hardly strong enough to bear the weight of snow or even the pressure of a ladder.

Zinc gutters, not being so strong as those of iron, require stays about 1 foot 6 inches apart. These are simply hollow cylinders of zinc—placed across the gutter—through which is passed the screw fixing the gutter to the

[1] For the thickness of the various gauges see p. 344, Part III.

[2] Sc. *Rhones.*

wood-work. The stay keeps the upper part of the gutter from bending inwards as the screw is driven home.

The various gauges for zinc and other metals are given in Part III., whence the following remarks are taken.

Zinc should not be allowed to be in contact with iron, copper, or lead. In either case voltaic action is set up, which soon destroys the zinc. This occurs especially and more rapidly when moisture is present.

Zinc should also be kept clear of lime or calcareous water, and of any wood, such as oak, which contains acid. Zinc laid on flats or roofs where cats can gain access is very soon corroded.

An objection to zinc for roofs is that it catches fire at a red heat, and blazes furiously.[1]

Glass is very frequently used as a covering for the whole or parts of roofs, such as those of railway stations, manufactories, etc. etc.

In some cases where a maximum of light is required, clear glass must be used ; but, as a rule, patent rolled rough plate will admit sufficient light, and it is always much stronger.

The glass is laid upon sash bars of iron or wood. The former may be of cast-iron, similar in section to wooden sash bars, or of wrought-iron of ⊥ section. The unequal contraction of iron and glass renders it difficult to keep a tight joint between them.[2]

Asphalted Felt.—This material is, as has already been noticed, often used under slates on account of its being waterproof and a non-conductor of heat.

It is, however, also adapted as a roof covering alone, for temporary buildings, being fixed to boarding by copper, zinc, or iron clout nails (the last being dipped in oil). The felt should be stretched tight, the joints between the pieces overlapped, and the whole paid over with hot tar and lime boiled together, and then sanded.

Willesden paper and *wire wove roofing* are also used for temporary roof coverings, and are described at pages 454, 455, Part III.

[1] Bloxam. [2] For patent systems of glazing see Part II.

Chapter XIII.

SLATING.

Pitch.—The general question of the proper "*pitch*," or inclination for different roof coverings, has been entered upon in Chap. XII.

As slating is here alone referred to, it will be sufficient to state that experience shows the minimum pitch for slates of different sizes to be as follows:—

	Inclination of Sides of Roof to Horizon.	Height of Roof in parts of Span.
Large slates . .	22°	$\frac{1}{5}$
Ordinary slates . .	$26\frac{1}{2}$°	$\frac{1}{4}$
Small slates . .	33°	$\frac{1}{3}$

The more severe the climate, and the smaller and lighter the slates, the steeper should be the roof, otherwise the wind will lift the slates and blow the rain up under them. A high roof, however, is of course more expensive, as it contains for the same span more timber and more surface to cover than one of flatter pitch.

Slates are laid either upon boarding or battens.

Boarding costs more than battens, but keeps out the wet and heat better, and is almost necessary for light slates.

Battens may be used for heavy slates, and are nailed upon the rafters at a distance apart equal to the "gauge." (See p. 217.)

The scantling of the battens used with rafters 12 inches apart varies from 3 inches by 1 inch for large slates to $2\frac{1}{2}$ inches by $\frac{3}{4}$ of an inch for the smaller sizes.

Names of Parts.—The "*back*" of a slate is its upper surface.

The "*bed*" is its under surface.

The "*head*" is the upper edge of a slate.

The "*tail*" is the lower edge.

The "*margin*" is the part of each course exposed to view on the outer surface of the roof.

The "*lap*"[1] is the distance by which each slate overlaps the

[1] Sc. *Cover.*

next slate but one below it. This should never be less than $2\frac{1}{2}$ inches or 3 inches. The flatter the roof the greater should be the lap.

The "*gauge*" is the depth of the margin.

Lap and Gauge for Slates nailed near the Head.—The "lap" and "gauge" are generally more accurately defined as follows:—

The "*lap*" is the distance between the tail of any course and the nail hole of the next course but one under it.

The "*gauge*" is half the difference between the length of the slate (*measuring from the nail hole*) and the lap.

For example, with "ladies" ($16'' \times 8''$) nailed at the head, as shown in Fig. 411, $\frac{16 \text{ in.} - 1 \text{ in.}^* - 3 \text{ in.}}{2} = \frac{12 \text{ in.}}{2} = 6$ inches (the gauge); with "countess" slates ($20'' \times 10''$) similarly nailed, $\frac{20 \text{ in.} - 1 \text{ in.}^* - 3 \text{ in.}}{2} = \frac{16 \text{ in.}}{2} = 8$ inches (the gauge).

With countess slates nailed at head having a 4″ lap the gauge would be $\frac{20 \text{ in.} - 1 \text{ in.}^* - 4 \text{ in.}}{2} = 7\frac{1}{2}$ inches.

* One inch is deducted from the full length of the slate, being the distance from the nail hole to the head.

Lap and Gauge for Slates nailed near the Centre.—The last-mentioned definition of lap and gauge refers, however, only to slates nailed near the head (see Fig. 410). When slates are nailed near the centre (see Fig. 412) the lap is the distance between the tail of any course and the head of the course next but one below, and the gauge is equal to half the difference between the lap and the *full length* of the slates.

Thus with countess slates, 20 inches by 10 inches, nailed near the centre, the lap being 3 inches, the gauge is $\frac{20 \text{ in.} - 3 \text{ in.}}{2} = \frac{17 \text{ in.}}{2} = 8\frac{1}{2}$ inches.

For countess slates nailed near the centre and laid with 4 inch lap the gauge would be $\frac{20 \text{ in.} - 4 \text{ in.}}{2} = 8$ inches.

The gauges for all the different sizes of slates nailed in either way are given at p. 222.

Preparing and Laying Slates.—The slates are first carefully squared to size, except the heads, which may be left rough, but not concave, the edges straightened, each punched with two nail holes, and the whole sorted, if necessary, into three thicknesses.

The slates should be trimmed with the smooth face up, in order that the bottom edge next to the smooth face may lie close, and that the countersunk side of the nail hole may be uppermost to take the head of the nail.

In laying the slates the great object to be attained is that the

bottom edge, or "tail," of every slate should fit as closely as possible to the backs of those immediately below it; they should therefore be laid (except the lower slates of the doubling courses) with their smooth sides downwards. The sections of the slates will therefore be as shown in Fig. 411—the bed being a little longer than the back, and the edges ragged and splayed; but they are generally drawn square-edged, as in Fig. 413 and others. The vertical joints between the slates should be as close as possible, and each should fall on the central line of the slate below.

Fig. 410.

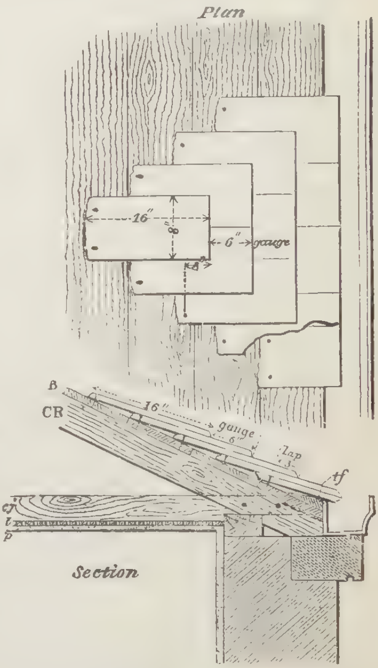


Fig. 411. *Slating on Boards nailed near Head.* Scale $\frac{1}{2}$ in. = 1 ft.

N.B.—The thickness of the slates in this and other figures is exaggerated, and the graining of the boarding is in Fig. 410 shown in order that the slates may stand out more clearly.

In good slating, the vertical joints of the alternate courses should range in straight lines from ridge to eaves, and the tails of the slates should be in perfectly straight horizontal lines.

Nailing Slates.—There are two methods of nailing slates, which differ very considerably, and will each be described separately.

1 *Nailing near the Head.*—In this method the nail holes are pierced at about an inch from the head of the slate, and the tails of the next course but one above override the nail hole by the specified "lap."

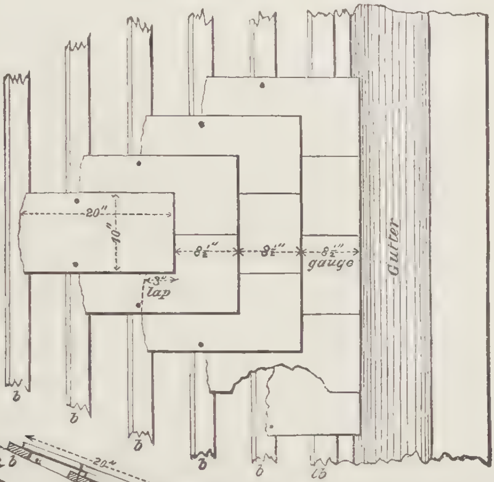
This plan used to be universally adopted, and is still in vogue, especially for very small slates.

It is preferred by some, because there are two slates over every nail hole, so that, when a slate is broken, the nail below is still covered by one slate, and thus protected from the weather. On the other hand, however, when the slate is nailed near the head, the wind acts upon it with a leverage equal to nearly its whole length. This makes a considerable difference if the slate is large,

and renders this system inferior, as a rule, to the methods shown in Figs. 412, 413.

Common or small slates secured with one nail only are necessarily fastened in the centre of the head.

Fig. 412.



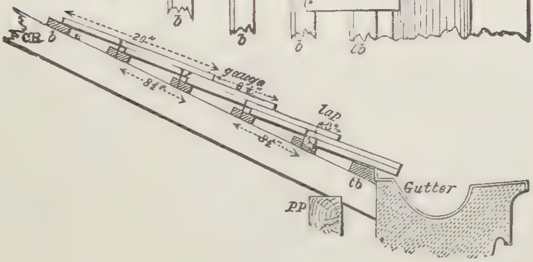


Fig. 413.

Slating on Battens nailed near Centre. Scale ½ in. = 1 ft.

2) *Nailing near the Centre.*—In this arrangement, Fig. 412, the nail holes are placed near the centre of the slate at a distance from its tail equal to a little more than the gauge + lap, so as to clear the head of the slate below.

This is a plan of more recent introduction than the other, and is preferable for large slates, as from the position of the nails the wind acts upon the slates with a leverage of only about half their length. Moreover, the slating so laid is easier to repair. It is, however, objected to by some, as the breakage of one slate exposes the nail of the slate below to the weather, and opens a direct communication with the roof through the nail hole.

With the same size of slates and same nominal depth of lap,

the gauge is, under this arrangement, wider than when the slates are nailed at the head; it is therefore evident that fewer slates are required to cover the same area, and that this plan of nailing is more economical than the other. The so-called three-inch lap is, however, in this case really only barely 3 inches, whereas in the other method it is practically 4 inches.

Nails.—In the best work slates are secured with copper nails, but zinc and "composition" nails are sometimes used, or simply iron nails dipped in boiled oil to preserve them from corrosion. In iron roofs slates are sometimes laid on angle irons, and may then be secured with copper wire.

The nails should be proportioned to the size of the slates, both in length and stoutness, and should have large heads, thin and flat, so that they may not prevent the slates from lying close.

In good work every slate should be secured with two nails, and in exposed places three have been used, though in very common work one nail only for each slate is often permitted.

In exposed situations the oversailing slates of gables should be secured by copper screws.

In nailing care should be taken not to bend or strain the slates, or they will crack, and fly under sudden changes of temperature.

EAVES AND RIDGE COURSES, etc.—If the slates vary greatly in size they should be assorted in lots, and the breadth of the courses decreased gradually from the eaves upwards.

The thickest slates should be in the lowest courses.

The lowest course of all, called the "*doubling eaves course,*" is laid with a double layer of slates, the lower one being cut so as to be about one inch longer than half the length of the uncut slates.[1] The highest or "*ridge course*" is also a double one. The slates in these courses are nailed near the head.

The eaves course is supported and the tails of the slates kept well up by a wedge-shaped board called a "*tilting fillet*"[2] (*tf*, Fig. 411), or "*eaves board.*" This prevents any open space occurring under the tails of the slates into which the wind could penetrate so as to loosen the slates and make them rattle. When battens are used the effect of the tilting fillet is produced by a "*tilting batten,*" thicker than the others. (See *tb*, Fig. 413.)

In the hips and valleys the slates have to be cut off obliquely to fit the angles; in the angles of valleys, and also where walls, chimneys, or windows cut into the roof, they have their sides slightly raised by means of tilting fillets running parallel to the valley. (See Fig. 439.)

[1] Sometimes the under course is formed of uncut slates laid lengthways, but this should not be allowed.

[2] Sc. *Doubling.*

Hips and Ridges are frequently covered with lead, as described at p. 241.

Slate Fillets are sometimes used to cover ridges. They are nailed on to the head of the ridge piece, so as to project and cover the joint between its sides and the top course of slates, the space between the under side of the fillet and the slates being pointed in cement.

Slate Ridging consists of a roll and sides formed out of thick slate. There are various patterns connected in different ways, which cannot here be described.

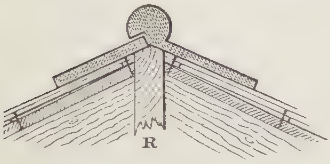


Fig. 414.

A common form in which the roll and one wing are in one piece is given in Fig. 414.

Another form having the roll and wings in separate pieces, the two latter being secured together with copper screws, is shown in Fig. 528.

The top of the ridge piece is kept higher than the slates in order that it may be bevelled off to receive the ridging.

Slate ridging is generally somewhat twisted, and very difficult to keep in straight lines when laid in long lengths.

Tile and Pottery Ridging is frequently used with slates, especially with those of a coarse description. In common work a semicircular tile is used, in better work tiles similar in form to slate ridging with high or "full crest" or low "half crest." The ornamental cresting may be detached, fitting into a groove in the roll.

Slating for Iron Roofs.—In covering iron roofs the slates may be laid on boarding or battens, or upon angle-iron laths filled in with wood and fixed at the proper gauge, in exactly the same way in which they are laid on wooden roofs (see p. 288).

When it is wished to make the roof fireproof the woodwork may be entirely dispensed with by laying the slates directly upon angle-iron laths (as in Fig. 548), to which they are secured by copper nails or wire bent round the laths, by copper or zinc clips, or by leaden pegs.

Shouldering.—In exposed situations, especially when the slates are rough, their heads are imbedded for a width of about two inches in hair mortar, mixed with ashes (so as to resemble the slates in colour). This is termed "shouldering." It keeps the slates down tight at the tails, and effectually prevents the wind from penetrating.

RENDERING.—Slates laid on battens are frequently rendered all over the under side with lime and hair. This may be done even when the roof is boarded, in order to give the slates a firm bed and to enable them to withstand traffic over them.

TORCHING.—Sometimes the slates are laid dry, and the joints between the tails of one course and the heads of another are afterwards pointed from the inside with hair mortar; this, however, does not last long under changes of temperature.

FELT.—The boarding is frequently covered with felt, which delays the passage of heat and cold, and keeps the roof dry in case of defects in the slating. It is a good plan to fix battens upon the felt, to which the slates may be better secured, so as to have a circulation of air just above the felt, which preserves it from decay.

TABLE showing the SIZES and WEIGHTS of SLATES and the numbers required for ROOFING.

Name of Slate.[1]	Size.	Gauge for 3-inch lap nailed in centre.	Gauge for 3-inch lap nailed 1 inch from head.	Number of squares covered by 1200.	Weight of 1200. 1st quality.[3]	Number required to cover one square.	Weight per square. 1st quality.[3]	Nails required per square.	
								Iron.	Copper.
	Inches.	Inches.	Inches.		Cwts.		Cwts.	Number.	lbs.
Singles[2] .	12 by 8	4½	4	2·8	17½	430	6¼	860	5
Doubles .	13 by 6	5	4½	2·5	15	480	6	960	6
Ladies (small)[4]	14 by 12	5½	5	5·0	31	240	6¼	480	3¼
Do. (large)	16 by 8	6½	6	4·¾	25	300	5½	600	3½
Viscountesses[5]	18 by 10	7½	7	6·0	36	200	6	400	2¾
Countesses .	20 by 10	8½	8	7·0	40	171	5⅔	342	4
Marchionesses[6]	22 by 12	9½	9	9·4	55	130	6	260	3¼
Duchesses .	24 by 12	10½	10	10·0	60	125	6	250	3
Princesses .	24 by 14	10½	10	12·¾	70	94	5½	188	3
Empresses .	26 by 16	11½	12	15·½	95	79	6⅓	158	3½
				Squares Covered by 1 ton.					
Imperials .	30 by 24	13½	...	2·5	...	48	8	96	3
Rags . .	36 by 24	16½	...	2·2	...	40	9	80	3½
Queens . .	36 by 24	16½	...	2·5	...	40	8	80	2

[1] Besides these there are intermediate sizes such as "*broad ladies*," "*long ladies*," "*doubles*." A fuller list is given in Part III.

[2] *Singles* are sometimes 10″ × 8″. Slates 12″ × 8″ are sometimes called *wide doubles*, sometimes *smalls*.

[3] Slates of inferior quality are thicker and heavier.

[4] Sometimes called *wide headers*.

[5] Sometimes 18″ × 9″.

[6] Sometimes 22″ × 11″.

SLATE SLABS are sometimes laid without boards from rafter to rafter, the lap being as usual, the side joints being covered with narrow slips of slate bedded in putty. They save the expense of boarding, but are very heavy, costly, and easily broken.

LARGE SLATES.—A very economical system of slating with large slates is as follows :—The rafters are placed at a clear distance apart about $1\frac{1}{2}$ inch less than the width of the slates. Down the centre of each rafter is nailed a fillet, thus forming a rebate on each side, in which the edges of the slates rest, being secured by black putty, or—as this looks smeary and uneven—by a second fillet 2 inches wider than the first, nailed over it so as to cover the edges of the slates and hold them down. Each slate laps about 3 inches over the one below it; only half the number is required in this as compared with the ordinary method of slating, and no boarding or battens are necessary.

ORNAMENTAL SLATING.—Slating is sometimes laid in patterns, and also lozenge-wise—that is, with the angles up and down, but this latter arrangement forms a less durable covering than the ordinary method.

OPEN SLATING[1] is sometimes used for sheds or other inferior buildings.

The slates, instead of being laid with close side joints, are about $1\frac{1}{2}$ inch to 4 inches apart. This requires only about $\frac{2}{3}$ the number of slates used for the ordinary method, and keeps out the wet sufficiently for very common purposes.

[1] Sometimes called *Half-Slating*.

Chapter XIV.

PLUMBERS' WORK.

THE work of the plumber includes laying sheet lead or zinc[1] on roofs and "flats," forming gutters and flashings, lining cisterns, fixing pipes and fittings for water supply and other purposes, also pumps, baths, water-closets, etc.

Laying Sheet Lead.—The surface to be covered with sheet lead is generally boarded. It should be perfectly smooth, even, and the boards thick enough to prevent their warping, otherwise the lead is liable to be damaged by their sharp edges.

If possible, the boards should be laid in the same direction as the fall of the flat or gutter, so that if the boards should warp across their width, the uneven ridges formed will not cause water to lie upon the lead.[2]

All sheet lead should be laid with a "current" or slope to throw off the water.

The amount of inclination varies according to circumstances; in gutters it must depend greatly upon position, and the space available for the fall. In any case, the current should not be less than 1 inch in 10 feet ($\frac{1}{120}$), but on flats, where there is no difficulty, it may be made 3 inches in 10 feet.

In order to guard against the effects of contraction and expansion in large pieces under the influence of changes of temperature, nothing larger than a sixth of a sheet—that is, a piece about 10 feet by 3 feet 9 inches—should be used.

For the same reason, sheets of lead should on no account be rigidly fixed on both sides, nor should they be soldered to one another.

[1] The description of the method of laying zinc has been given in Chap. XII.

[2] Lead is described as "6 lb. lead," "5 lb. lead," according to its weight per square foot. 6 lb. to 8 lb. lead are commonly used for Flats, Gutters, etc., 5 lb. lead for Flashings, 6 lb. and 7 lb. for Hips and Ridges, or greater weights if the work is much exposed. (See Part III.)

The joints necessary between adjacent sheets are made in various ways, so as to allow sufficient play for contraction and expansion.

The joints in the direction of the "current" are made with "*rolls*," while "*drips*" are used for those joints which run across the current.

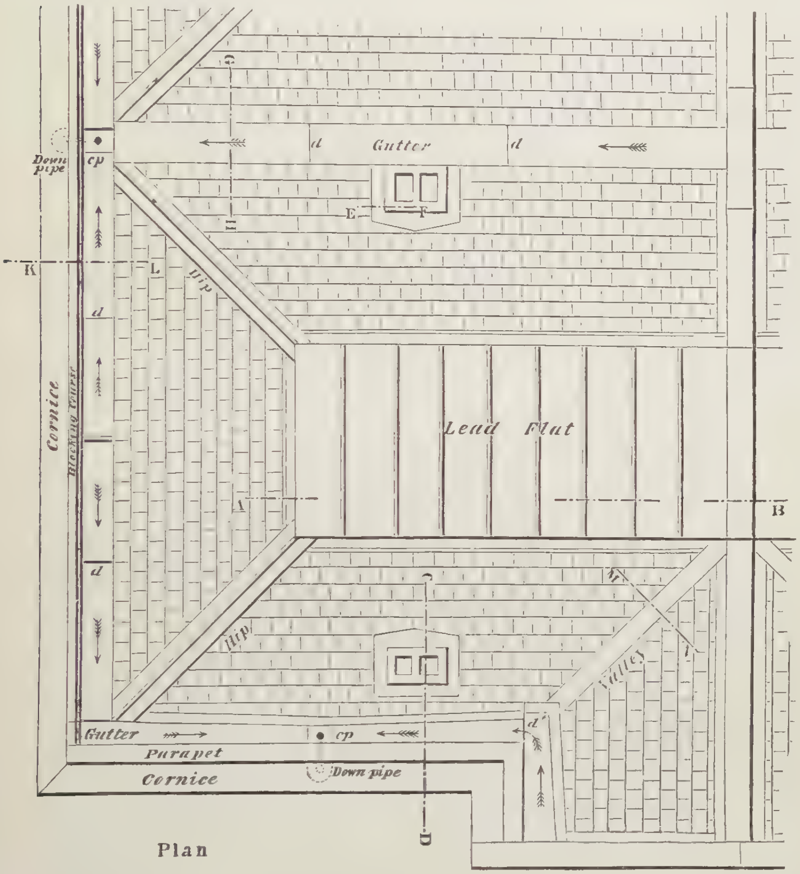


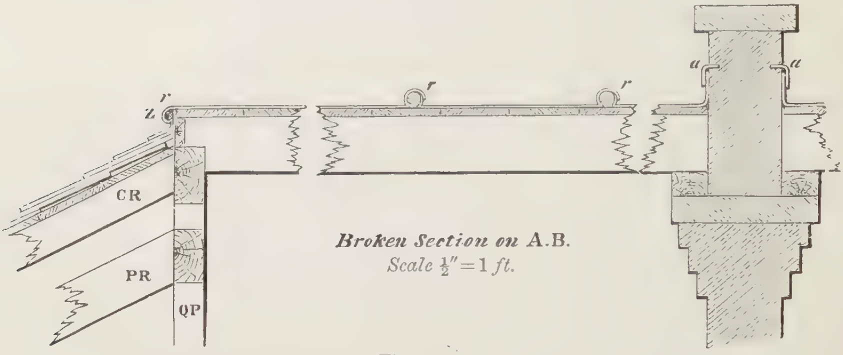
Fig. 415.

Fig. 415 is the plan of a portion of two roofs arranged so as to show a lead flat, a valley with trough gutter between the roofs,[1] a gutter behind a blocking course, also one behind a parapet wall, a valley in the angle formed by two portions of one roof,[2] together with hips, chimney and gable flashings, cesspools, drips, etc.

[1] *Middle Gutter.*

[2] Sc. *Flanks.*

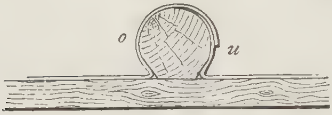
Most of the subsequent figures, 416 to 439, are sections on the lines marked and lettered on Fig. 415, giving details showing how the lead is fixed in the different parts of a roof.



Broken Section on A.B.
Scale ½″=1 *ft.*

Fig. 416.

Rolls are joints between two sheets on a flat (*r r* Fig. 416), formed by fixing under the junction of the sheets a piece of wood about 2 inches diameter, having its upper surface rounded and the lower corners either left square, or chamfered off as shown in Fig. 417. This wooden roll is overlapped by the edges of the adjacent sheets. One of these, *u*, the "*undercloak*," is hammered and dressed closely in to cover the roll, reaching as far as the crown, and the edge of the other sheet, *o*, the "*overcloak*," is then beaten and dressed down over the first, as shown.



Enlarged Section of Roll

Fig. 417.

The laps should be on the least exposed side of the rolls, so that the wind may not blow the lead up, and allow the rain to get under it. Thus in London it is the rule to cloak away from the south-west. The rolls should be about 2 feet apart, sometimes less, but never more than 2 feet 3 inches.

Bad form of Roll.—In many cases the inner sheet is dressed right over the roll down to the flat on the other side. This is a waste of lead, and is injurious to the work, for it confines the sheet so much that it cannot expand and contract under changes of temperature.

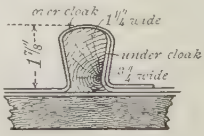


Fig. 418.

In many cases a roll such as that in Fig. 418 is used. It is lighter but not so substantial a form as that in Fig. 417.

The outer sheet is frequently continued right over the side of the roll and doubled down, so that about an inch or more lies

upon the flat as in Fig. 418. This is intended to make the joint more secure, but is objectionable, not only because it confines the lead, but also because the water lying upon the flat gets in between the sheets of lead and is drawn up by capillary attraction, so as to pass the joint and soak into the wood rolls and boarding.

Hollow Rolls are in some parts of the country[1] preferred to those with the wooden roll or core.

The ends of two adjacent sheets are turned up against one another as at O, Fig. 419, the upper edge of one being bent down over the other; the two are then bent over together to form a roll as at P.

Between the ends of the two sheets so treated is a "clip" or "tingle"[2] (shown in Fig. 419 by a thick line). This is a narrow strip of lead, of which about 2 inches is nailed to the boards.

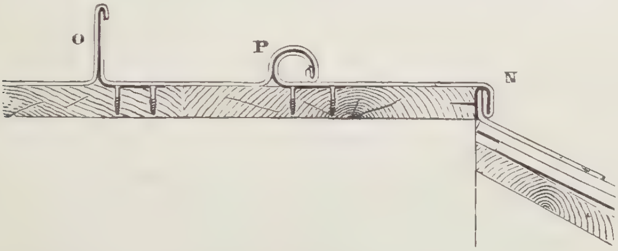


Fig. 419.

Similar tingles are fixed at intervals of about 2 feet throughout the length of the rolls, and, being turned over between the ends of the sheets in forming the rolls, secure the latter firmly to the boarding.

The ends of the hollow rolls are dressed over the *nosings* forming the sides of the flat.

Nosings are rolls formed at the angle between the horizontal surface of the flat and the sloping sides of the roof.

The upper half course of slates is first covered by a flashing, which is dressed about 8 inches upon the slope, turned up, and terminated at the angle of the flat. Upon this is secured a wooden roll, undercut on the lower side, as shown at Z, Fig. 416. Over the roll the lead of the flat is dressed in a manner similar to that above explained.

Occasionally the roll at the edge of the flat is formed with its base upon the top of the boarding in the same way as the other rolls on the flat. This is considered by some to have a better

[1] Chiefly in Scotland and the north of England.

[2] Sc. *Latchet.*

appearance than the nosing, as it forms a sort of ridge which ranges with the ridges of the hips of the roof.

Hollow Nosings may be formed on the same principle as hollow rolls (see N, Fig. 419). This figure shows a flat nosing, but they are often made round or "*bottled*" for the sake of appearance, being then in section like the roll P, but with the base vertical.

Welts (see Fig. 420) are formed by bending up the adjacent edges of two sheets—turning one over the other, and then dressing them down close to the flat. When very exposed they are further secured by tingles.

Fig. 420.

They take up less room than rolls, and are common on curb roofs, but do not form so good a joint.

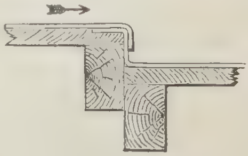
Seams are the joints made between pieces of lead by soldering.

Lapped Joints are those in which one sheet is dressed down flat and the edge of the adjacent sheet over it, so as to lap from 4 to 6 inches.

This joint is used chiefly between the different portions of long and narrow pieces of lead, such as flashings, coverings for hips, ridges, valleys, etc., and generally lies across the current.

Drips are joints made across the current of a sheet of lead, thus :—

The surface to be covered is interrupted by steps from $1\frac{1}{2}$ to 3 inches in depth (the deeper the better), running across it at intervals of about 8 or 10 feet. The lower sheet is first laid, dressed close up to and over this step, and its upper edge is generally fitted as in Fig. 421 into a rebate cut for it in the boarding of the higher level of the drip so as to avoid a ridge.



Section of Drip

Fig. 421.

The upper sheet overlaps the lower, and is turned down over it as shown. This upper sheet should stop $\frac{3}{4}''$ short of the horizontal sheet below, otherwise the wet will be drawn up, by capillary attraction, between the sheets into the boarding above.

The upper lead is often carried down so as to form an overcloak resting an inch upon the flat. This is objectionable, as moisture is drawn up by capillary attraction. The rebate in the upper boarding is sometimes omitted and the upturned lead stopped $\frac{1}{4}''$ short of the upper surface of the drip.

Five drips are shown at *dd* in the gutter, Fig. 415, and Fig.

421 represents a section of one of them; the arrow shows the direction of the flow of water.

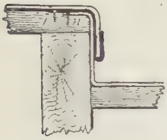


Fig. 422.

Drips for exposed places.—Fig. 422 shows a form of drip used in flats and long lengths which have a tendency to blow up.

When long lengths of lead are used, tacks or clips (*c*), as shown in black in Fig. 422, may be fixed at about 18 or 20 inches apart. The upper end of the lower lead is frequently nailed to the boarding as shown. The tack is usually nailed through the lead below, but it is better to make it extend beyond and nail it separately as shown.

Fig. 423 shows another form of drip used where there is much exposure to wind. It explains itself, and so does Fig. 424, which is used in similar situations and called a *clinch*.[1]

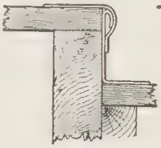


Fig. 423.

Fig. 424.

BOTTLENOSE DRIPS.—In some parts of the country a drip, such as that in Fig. 421, is formed thus:—The boarding on the upper level is allowed to project an inch or so over the bearer; the lower sheet of lead is turned up until it reaches the lower side of this projection, or "bottlenose"; the upper sheet is dressed round the projection, and hangs down over the turned-up lead, to form the apron.

Fixing Lead to Masonry.—A RAGLET is a groove about an inch deep, and as narrow as possible, cut into masonry or brickwork to receive the edge of sheet lead to be fixed to the walls.

WEDGES, WALL-HOOKS.—The lead-flashing, *lf*, Fig. 425, may be secured in several ways—by wooden or lead wedges[2] (*lw*) driven in tight between it and the edge of the raglet, or by wall-hooks[3] (*wh*), which are short, flat-shanked spikes of bar iron with one end hammered thin and bent over at right angles to form a head. The lead wedges are more adapted for use in stonework, and the wall hooks in brickwork.

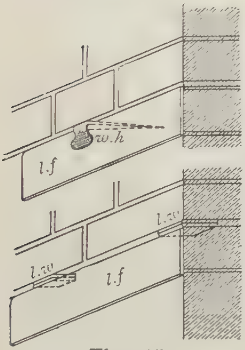


Fig. 425.

The joint is generally pointed and made good with cement or mastic.

BURNING IN.—When the raglet is formed along the top of a course, as shown in Fig. 435, and a very secure joint is required, to withstand exposure, the lead may be "burnt in," which consists in inserting the edge of the sheet in the raglet

[1] *Buchan.* [2] Sc. *lead bats.* [3] Sc. *Thumbats.*

groove, and filling the latter with molten lead, which is then well punched or "caulked" in.

Lead Dots or **Solder Dots.**—In some cases—for example, in covering a small dome with sheet lead—it is necessary to screw the lead to the woodwork. The screws are generally used in pairs (see Fig. 426), inclining inwards toward one another, and the boarding is countersunk, so that the heads of the screws are well below the surface of the wood. Into the hollow thus formed, the sheet lead is dressed and screwed down, and then a patch of molten solder (a *lead dot*) is "*wiped*" in, so as to protect the screws, and bring the whole to an even surface. The screws must be left standing up from the lead so that the solder may get a good hold of them. If screwed right home they would pull through the lead if the wind tended to lift it. If the boarding is not hollowed out where the lead dots occur, they of course project above the surface. The heads of nails may be similarly protected.

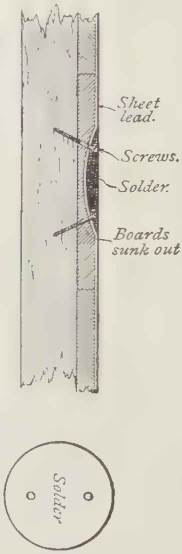


Fig. 426.

Flashings are pieces of sheet lead placed so as to cover joints which would otherwise admit wet to the roof timbers, or other parts of the building.

The term is frequently applied to a piece of sheet lead fixed to a wall, and *hanging over*, so as to cover the edge of a gutter or other sheet lead turned up against the wall, and to protect the joint between the lead and the masonry. (See *aa*, Fig. 427.)

In some parts of the country, however, this particular flashing is known as a "*cover-flashing*" or "*apron*."

The term "*flashing*" will be taken in these Notes to include the whole of the lead used for the protection of a joint, and "*cover-flashing*" or "*apron*" to refer only to the overhanging piece.

The flashings principally required in a building are over the joints formed where a roof is cut through by a wall, chimney, skylight, or dormer window.

The flashing may be fixed in various ways; it may lie over the slates as in Fig. 429, or under them, as in Fig. 430.[1]

The portion turned up against the wall should be 5 or 6 inches

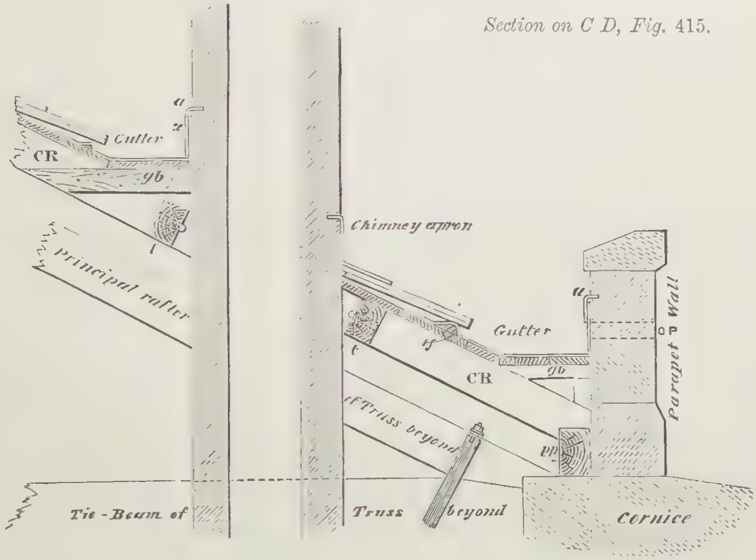
[1] This kind of flashing may be considered a form of gutter.

high, and may itself be secured in a raglet, or the turned-up end may be left free, so as to allow contraction and expansion, and be covered by an apron.

An Apron or Cover-Flashing is a covering piece of sheet lead, of which the upper edge is turned into a raglet, and there secured as above described. The remainder is turned down, and hangs freely over the upright part of a flashing or gutter.

Fig. 427.

Section on C D, Fig. 415.



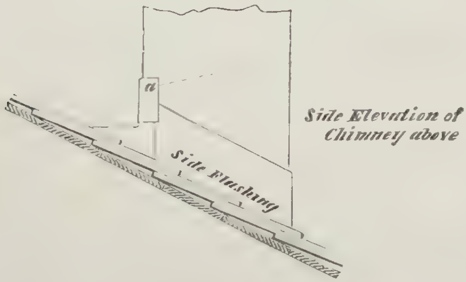


Fig. 428.

When the side or end of a gutter or flat is turned up against a wall, the joint between the wall and the upturned lead is thus securely covered and protected from wet, while the lead is free to expand and contract under changes of temperature.

In the best work, sheets of lead which are wide, or of which the outer edge is fixed, should never themselves be secured to the wall, but should be connected with it by means of an apron.

Some authorities recommend that the apron should be of the same width as the upturned lead, as shown at *x* in Fig. 427, so that it may not be liable to be blown up and expose the joint; this, however, is generally considered a waste of material, and it is objectionable, for it leads to the sucking up of moisture past the joint by capillary attraction. The apron is therefore usually turned down only 3 or 4 inches over the edge of the upstanding lead, so that the lower edge may be clear of any wet which lies upon the horizontal sheet of lead below.

Chimney Apron.—The flashing between a wall or the side of a chimney and the roof that slopes down from it is also frequently called in England an "apron," and in Scotland a "berge."

It is a simple flashing, formed out of lead some 15 or 16 inches wide, of which 6 or 8 inches may be dressed over the slates down the slope, 6 inches upturned against the chimney, and the remainder fixed in the raglet.

Horizontal Flashings.—When a joint occurs between a horizontal surface, such as a lead flat, and a wall or chimney, the lead is dressed up against the masonry to a height of from 5 to 7 inches, and the joint covered by an apron, as at *a* in Fig. 416.

Raking Flashings are required to cover the joint which exists where the slope of a roof is cut into by a wall or chimney.

There are two methods of arranging the flashing.

1. The strip of lead required should be about 16 inches wide; of this, 8 inches lie[1] upon the slates; 6 inches are turned up against the masonry, and the remainder into a raglet parallel to the slope, and secured there.

A tilting fillet[2] is fixed in the angle formed by the wall and roof boarding, which raises the sides of the nearest slates, so as to throw off the water.

The section, Fig. 429, shows this arrangement; it is taken through the lap of the slates where there are, of course, three layers.

An additional precaution is sometimes taken by forming a

[1] This is when countess slates are used. The width should be 3 inches more than half that of the slate, so as to overlap the first side joint 3 inches.

[2] Sc. *Doubling.*

cement fillet, of triangular section, under the lead flashing in the angle between the slate and the wall, so that if the flashing is blown up, the joint is still kept secure until the lead is replaced.

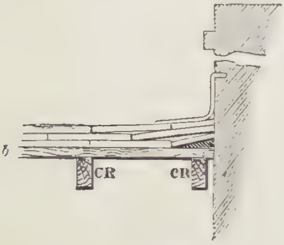


Fig. 429.

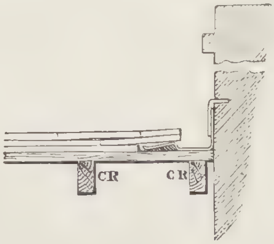


Fig. 430.

2. In the second method a tilting fillet about 2 inches wide and $\frac{3}{5}$ inch at the thickest part is placed from 2 to 4 inches from the chimney or wall, and the lead dressed close over it, and down upon the roof boarding, which is sometimes rebated out $\frac{1}{2}$ inch in depth to receive it, then turning up against the wall and under a cover flashing or apron. The slates lie over the lead.

For deeper gutters the boarding may be lowered an inch or more and special beams provided for it.

Fig. 430 gives a section of this method as frequently carried out. It will be seen that it virtually forms a sort of gutter down the side of the chimney, and it is sometimes so described. This arrangement requires a little more lead than the other, but secures it better, for the lead, being under the slates, is not liable to be blown up. The wind is apt, however, to catch the exposed sides of the slates, and displace them. The remedy for this is to continue the slates right over the gutter until they nearly touch the chimney. When this is done, not only are they themselves protected from the wind, but they keep the sun off the lead, and prevent the latter from cracking.

The disadvantage of the arrangement last described is that when the gutter is covered by the slates its interior cannot easily be cleared out, and it becomes choked with dust and dirt, which lead the wet over the tilting fillet and into the roof boarding.

An elevation of a raking side flashing for a chimney is given in Fig. 428.

STEPPED FLASHINGS are generally used where large and wide chimneys, or gable walls, cut into the slope of a roof.

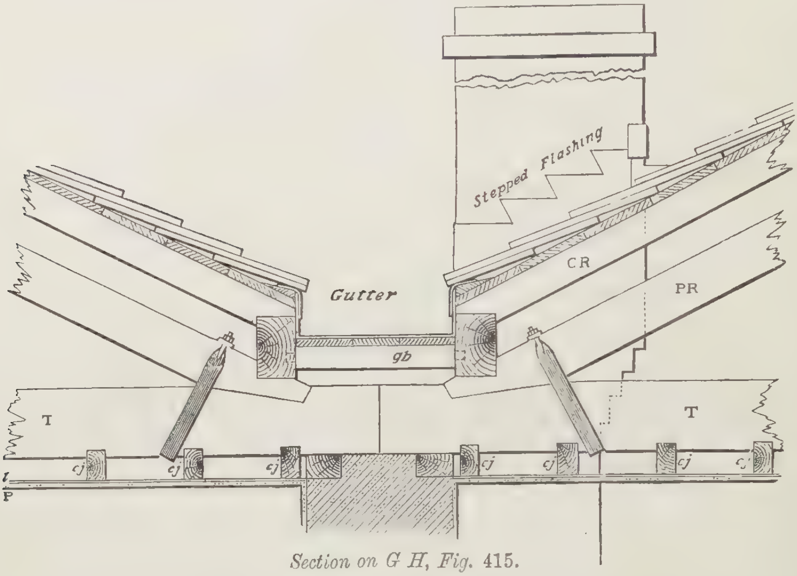
The raglet, instead of running parallel to the slope of the roof, is in short horizontal lines, and the lead is cut into steps, the ends of which are at right angles to the slope, as shown in Fig. 431.

This is a great advantage in brickwork, as it enables the raglet

to be formed by raking the horizontal joints, instead of cutting into the bricks.

There are several ways of fixing stepped flashing.

The most common is to use lead some 16 inches wide, of which 8 inches may lie on the slates, 6 or 7 inches turn up against the wall, and the remainder into the raglet.



Section on G H, Fig. 415.
Fig. 431.

The section in this case would be similar to Fig. 429, and the elevation as in Fig. 431, except that the edge of the lead lying upon the slates would be seen.

Another plan is to form a side gutter along the wall, as in Fig. 430, securing the upturned lead in a stepped raglet, or covering it by an apron all in one piece cut to fit the steps,[1] as shown in elevation, Fig. 431.

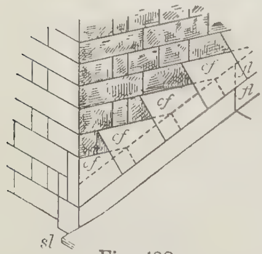


Fig. 432.

COVER-FLASHINGS IN SEPARATE PIECES.—A better flashing is formed as shown in Fig. 432 by hanging the stepped apron or cover-flashing in pieces (*cf cf*), one to each step, so arranged that the broad end of each piece overlaps the narrow end of the piece next to it down the slope, by 2 or 3 inches. These pieces may have a mean width of about 5

[1] Sometimes called a *Skeleton Flashing.*

inches, of which an inch is secured in the raglet, and the remainder hangs over the flashing. The flashing itself will be disposed, as in Fig. 430, over a tilting fillet under the slates; the upturned portion need not be more than 3 or 4 inches high, and will be covered by the stepped apron.

SOAKERS,[1] Fig. 433, are used instead of stepped flashing, and consist of pieces of lead (*sk*), worked in between the slates as they are laid; each piece is about 4 inches longer than the gauge of the slating (so that each extends under the whole exposed

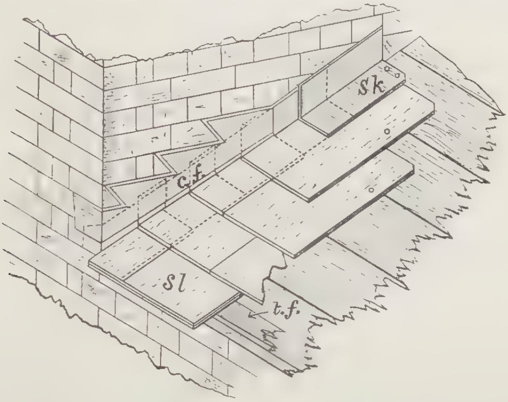


Fig. 433. *Soakers.*

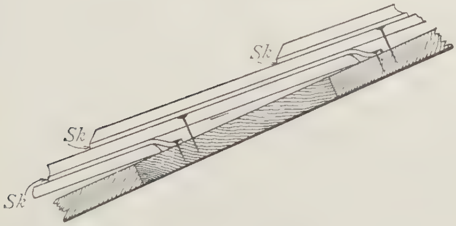


Fig. 434. *Section.*

portion of a slate, and laps 4 inches over the next soaker),[2] and about 14 inches broad, so that 6 to 8 inches may be under the slate, and 4 to 6 inches up against the wall, being covered by an apron or cover-flashing.

This form of flashing is now in very general use. It is simple and secure; the wind cannot lift it, the lead cannot be stripped off without removing the slates.

[1] Often also called stepped flashing.

[2] Soakers are sometimes made the full length of the slates, but this takes more lead and the soaker is pierced by the nail which secures the slate above it.

In some cases instead of nailing the soakers as shown, they are secured by bending over an inch along the top edge, so as to clip the head of the slate. This is not a good plan as it requires more lead and prevents the head of the slate from lying close to the boarding.

TINGLES[1] are fastenings placed at short intervals to prevent exposed sheet lead—such as flashings which lie upon the slates, lead upon ridges, etc., from being blown up by the wind. They consist of strips of sheet lead which are nailed to the boarding, or hooked on to the head of a slate, and bent over so as to clip the edge of the flashing.

Lead Gutters.—Two or three methods of constructing lead gutters are illustrated in Fig. 415, and the details connected therewith.

All gutters should have a current or fall of at least $\frac{1}{100}$, and the joints between the ends of the sheets should be formed, when possible, by drips not more than from 8 to 10 feet apart.

The sides of gutters which abut upon walls or blocking courses should be turned up from 6 to 7 inches against them, and be covered by an apron. The side is, however, frequently fixed by simply turning its upper edge into a raglet; as the other edge is trammelled by the tilting fillet, this prevents free expansion and contraction under changes of temperature, and often results in splitting the lead. The ends of lead gutters are either *bossed up*—that is, neatly beaten into shape—or else formed with *dog-ear joints*, the lead being folded like the end of a paper parcel. These last are, however, not considered to be good plumbing, as the lead when bent double is liable to crack.

BRIDGED GUTTERS are formed with sheet lead laid upon boarding, supported by bearers. These bearers may either be framed in between the timbers of the roof or merely nailed to them. In the former case they are called *trough* or *framed gutters*; in the latter case V gutters.

Trough[2] *or Parallel Gutters.*—Fig. 431 (being a section on G H of Fig. 415) shows a trough gutter formed in the valley between two roofs.

It consists of a gutter bearer (*gb*) framed in between the pole plates of the roof, which are placed upon the principal rafters, so as to afford room for the gutter.

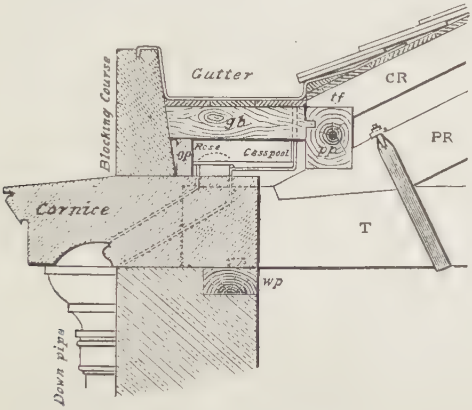
Boarding is fixed upon the gutter bearer, and upon this is laid

[1] Sometimes called Bale Tacks, Bell Tacks, Bail Tacks, Clips, Lappetts, Binders, Tails. Sc. *Latchets*. [2] Sc. *Box Gutter.*

the lead which passes up the slope on each side, and over the tilting fillet under the slates.

When a gutter is very deep and wide, so as to require a great width of lead, the sides sometimes stop short before they turn up the slopes of the roof, and are covered by an apron on each side hanging over the end of the rafter and the pole plate, as shown in Fig. 431.

A trough gutter fixed behind a blocking course is shown in Fig. 435, which is a section on K L, Fig. 415.



Section on K L, Fig. 415.
Fig. 435.

The bearer is framed at one end into the pole plate of the roof, the other end being supported by a gutter plate (*gp*).

One side of the gutter lead is turned up against the blocking course, and may be secured, as shown, by turning it into a raglet on the top.

It may, however, be covered by an apron, either similarly secured (see Fig. 147), or continued over the top of the blocking course and turned down about an inch over the front edge. In the last case the apron is kept in position by a conical-headed rivet leaded into the top of the blocking course.

The inner edge of the lead is turned up over the tilting fillet and boarding of the roof until it is higher than the top of the blocking course (or than the overflow pipe, if any), so that, in case the gutter should be choked, the water may flow over or through the blocking course, not over the inside into the building.

When the blocking course is high an overflow pipe may be introduced, as at OP in Fig. 427.

It is evident that the necessary fall for a trough gutter may be obtained by lowering the bearers gradually along its length, the width remaining the same throughout. The section, Fig. 435, is taken at a high part of the gutter, and the bearer is nearly up to the top of the pole plate; but in Fig. 431, which is a section at a lower point of the valley gutter, the bearer is nearly at the foot of the pole plate.

V *Gutters.*[1]—An example of a V gutter formed behind a parapet wall, and also of one behind a chimney, is shown in Fig. 427, which is a section on C D, Fig. 415.

The gutter bearers, instead of being framed into the pole plate of the roof, as in the trough gutter, are here nailed to the sides of the common rafters.

The lead is arranged as before, about 4 to 6 inches being turned up against the inside of the parapet wall and covered by an apron.

As the parapet is generally of considerable height, an overflow pipe should be inserted, as at OP, so that, in case of the gutter being flooded, the water may escape through the wall and not into the roof.

The end of the lead turned up the roof should be slightly higher than this overflow.

The necessary fall for a V gutter is obtained by lowering the bearer. It will be noticed that, as this brings it farther down into the angle between the slope of the gutter and the parapet wall, it has the effect of narrowing the gutter, which tapers in plan from the highest to the lowest level (see Fig. 415).

In arranging such a gutter, therefore, the points of exit for the water should be as frequent as possible, in order to avoid long lengths of gutter, for these spread out as they rise till they become very wide, and require a large quantity of lead. It will be noticed also, that as each drip raises the level suddenly, it has the effect of widening the gutter at the point where it occurs. An illustration of this is shown at *d′*, Fig. 415.

Fig. 427 shows a gutter formed at the back of a chimney where it cuts through the roof.

Such a gutter must be made of a size proportionate to the area of roof that drains into it.

It is constructed on the same principles as the ordinary V

[1] This name is sometimes applied to common arris gutters, formed with two boards fixed together at an angle.

gutter, being higher and consequently broader in the centre, so as to throw the water off on each side of the chimney.

If the chimney be against a wall, the water must, of course, be thrown off to one side only, and the gutter is broader at the end next the wall.

The apron at *x* in Fig. 427 is shown the full depth of the upturned flashing as an illustration of the remarks at p. 232.

Fig. 436 is a section of a V gutter formed between two roof slopes. The construction is similar to that just described, the fall being obtained by lowering the bearer. In the figure, the bearer is shown at the lowest point, and it will be seen that when

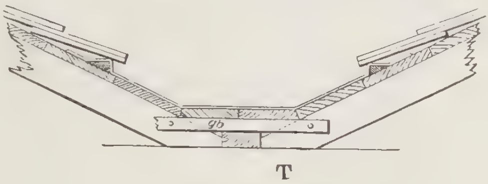


Fig. 436.

it is raised to higher levels, in order to procure the necessary inclination, the gutter will be widened considerably.

It is evident that troughs have great advantages over V gutters, inasmuch as they remain throughout of a constant width, and do not require a large, unsightly, and expensive width of lead. Drips can be formed without widening the gutter, and down pipes are not required to be frequent.

Stone Gutter lined with Lead.—Another form of gutter is that shown in Fig. 413, in which the lead is merely a lining to the gutter hollowed out in the cornice.

Such a gutter is very commonly used, especially in the North, but it is open to considerable objection. It is impossible, for want of depth, to form drips in the stone, and the lead must be in one long piece, composed of sheets soldered together, and liable to great contraction and expansion; or the joints between the sheets must be lapped, which makes the surface uneven and insecure.

Cesspools[1] are small cisterns formed in lead gutters at those points where it is intended to get rid of the water.

Fig. 415 shows two such cesspools, marked *cp* in plan. One of these is partly seen in elevation in Fig. 435.

[1] Sc. *Drip Boxes.*

The cesspool is a wooden box lined with sheet lead, turned up on all its sides, which are covered by aprons.

It should, if possible, be made the same size as the gutter. If not, it will be a source of trouble, and difficult to make water-tight.

In the illustration given in Fig. 435 a channel is cut through the coping connecting the cesspit with the head of the down pipe. The mouth of this communication is protected by a perforated zinc rose or grating, to prevent dead leaves or rubbish from getting into and choking the down pipe.

Iron Gutters are cast by the founder, but the work of arranging them generally devolves upon the plumber.

EAVES GUTTERS [1] run along the lower edges of the roof slopes, and are fixed in different ways.

Fig. 346 shows semicircular gutters[1] resting on holdfasts nailed to the boarding of the roof. The ogee gutter in Fig. 352 is secured at intervals to the fascia board. The moulded gutter in Fig. 531 rests upon the wall, and that in Fig. 524 on a projecting sailing course or upon corbels.

Both these positions should be avoided if possible, for where the gutter rests upon the wall it will be constantly leaking into it, causing damp, and injuring the masonry.

IRON VALLEY GUTTERS are often used, and may be obtained either of sections like V gutters gradually varying in depth and width throughout their length, or of uniform cross section throughout like trough gutters.

The V gutters must of course be cast to suit the pitch of the roof, or the pitch arranged to suit such patterns as may be kept in stock.

Fig. 522 shows a cast-iron trough gutter at the back of a parapet wall.

Zinc Gutters for eaves may be semicircular or moulded, and fixed in the same way as iron gutters; but zinc valley or trough gutters are laid somewhat in the same way as those of lead.

Rain Water Pipes.[2]—It has already been mentioned that all gutters should lead to vertical down pipes, which conduct the water to drains provided to carry it off.

These pipes are generally of cast iron, circular in section, and

[1] Sc. *Rhones* or *Runs.*

[2] Also called "Down-comers," "Stack Pipes," "Spouting," and "Rain Water Pipes." Sc. *Conductors, Wall Pipes.*

about 3 or 4 inches diameter, the size varying according to the amount of water they will have to carry off.

They are secured by spikes driven into the wall through ears cast on each length of pipe, or by collars with ears spiked to the wall, or by patent methods which cannot be described here.

Zinc pipes, and even lead pipes, are similarly used, but they are not common, and need not further be noticed.

The openings into heads of all down pipes should be protected by a rose similar to that shown in Fig. 435, to prevent dirt and rubbish from getting in and choking the pipe.

Ridges and Hips.—The lead used for covering these should weigh about 6 lbs. per superficial foot. It has to a great extent been superseded by the use of slate and tile ridges.

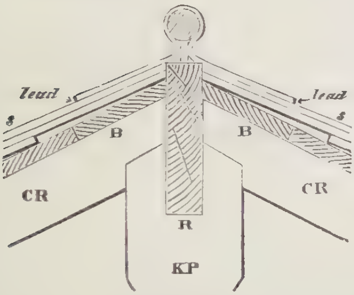


Fig. 437.

Ridges on the apex of the roof are covered with lead laid over a wooden roll fixed to the ridge piece. This lead is dressed well into the angles under the roll, and laps over the slates on each side about 6 or 8 inches, according to the size of the slates. It is generally left without any fastening, being kept down by its weight and the grip it has upon the under side of the roll.

It may, however, in exposed positions be further secured by either of the following methods:—(1) by securing the lead to the sides of the roll with lead-headed nails; (2) by sheet-lead ears soldered to the under side of the sheet and nailed to the boards on each side of the roll; (3) by straps or tingles (*t*, Fig. 438) of stout lead laid at intervals along the ridge over the slates, and secured to the top of the ridge by the spike which carries the roll. The ends of these straps are bent back and dressed down upon the extremities of the sheet lead covering the ridge, as shown in Fig. 438.

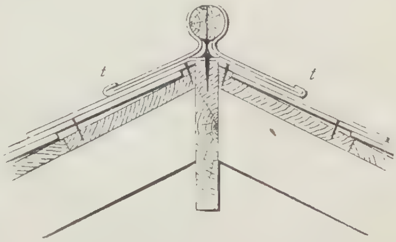


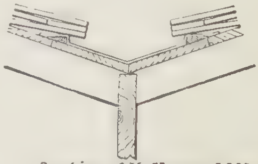
Fig. 438.

HIPS, which are the salient angles formed by the meeting of two roof slopes (see Fig. 415), are covered with lead in the same way as ridges, except that, as the sheets have a tendency to slide

down, they require to be nailed at the upper ends, the nails being covered by the lap of the sheet above.

The lead for covering hips varies from 18 to 20 inches in width, according to the inclination of the roof and the size of the slates.

VALLEYS.—In the valley formed by the intersection of two roof slopes forming a re-entering angle, such as that shown in Fig. 415, a strip of lead is laid on the boarding along the intersection of the slopes. The sides are turned up along the boarding for a distance of from 5 to 7 inches, and then dressed over tilting fillets[1] fixed parallel to the angle, so as to raise the sides of the adjacent slates.



Section of Valley on M.N.
Fig. 415.
Fig. 439.

The joints between the different sheets necessary in a long valley are lapped for a length of 4 or 5 inches.

Substitutes for Lead Flashings.—Sheet zinc is frequently used instead of lead for the flashings of inferior buildings. It is laid nearly in the same manner, but not quite so easily, and does not last so long, especially in bad atmospheres.

Cement flashings, or rather "*filletings*," are used in the very commonest work. They consist merely of triangular fillets of cement worked into the angles of joints to be protected. Hair mortar is used for filleting in the same way as cement.

Another form of cement flashing is thus constructed:—a row of nails is driven into the wall or chimney an inch or two above the joints to be protected. Round these is twined tarred oakum. This is then covered with cement forming a projecting ledge, which keeps wet out of the joint.

Courses of the brick or stonework are sometimes allowed to project over the joints in a similar way, or slates, tiles, or flat stones may be built in for the same purpose.

Cisterns.—The various forms of cisterns, and the lead pipes and apparatus connected with them, do not come within the limits of this volume, and cannot here be entered upon.

The lead used for lining cisterns must have soldered joints; but the water keeps it from expansion and contraction.

Joints for Lead Pipes.—The joints used for lead water pipes are as follows:—

The WIPED PLUMBERS' JOINT or ROUND JOINT, as shown in elevation at Fig. 440, and in section at 441.

[1] Sc. *Doublings.*

To form this joint the ends of both pieces of pipe are made quite circular by forcing into each a wooden *tampin*. One end is made of a larger diameter and trumpet-shaped, so as to form a socket for the other, the end of which should point in the direction in which the water in the pipe will flow, so as not to cause a check. The outer edges of both ends are rasped to form sharp arrises, so that they will socket together tightly. After fitting both ends should be blacked for about 6 inches in length with "*soil*."[1] When dry the ends are shaved, *i.e.* scraped clean to the length required for the joint, and a little tallow spread over the surface as a flux. Molten solder is then splashed or poured on and rubbed with a cloth to the shape shown at *s* in Figs. 440 and 441. Sometimes the socket may be larger, as dotted at *f*.

The Plumbers' Branch Joint is shown at 442 and 443.

The Blown Joint or Copper-bit Joint is shown at 444 and 445.

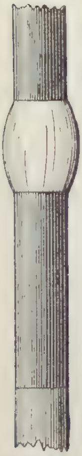


Fig. 440.

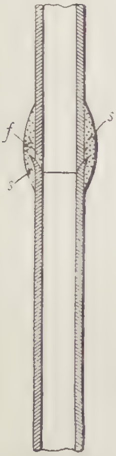


Fig 441.

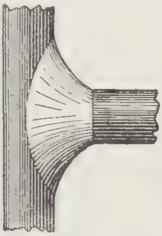


Fig. 442.

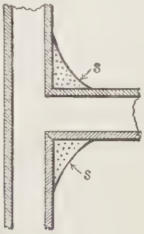


Fig. 443.

Fig. 444.

Fig. 445.

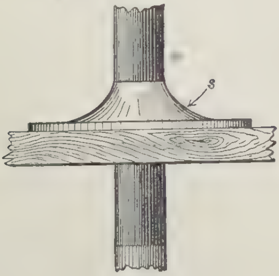


Fig. 446.

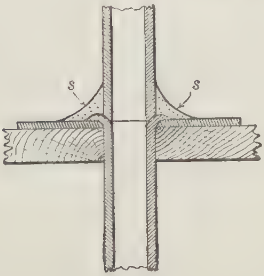


Fig. 447.

This joint, though sometimes used for lead pipes, is not good workmanship, and is used more by gasfitters and zincworkers than by plumbers.

The Plumbers' Flange Joint is shown at 446 and 447. This is useful when a pipe passes through a floor. The solder is sometimes used, even when there is no joint, to support the pipe at this point.

[1] A paint formed of size, lamp black, and chalk.

Chapter XV.

STEEL AND IRON GIRDERS.

CAST-IRON GIRDERS, BRESSUMMERS,[1] AND CANTILEVERS.[2]

GIRDERS of considerable length and those required to support a heavy load are generally of steel or iron.

A very slight description of one or two common forms of such girders will be given here, the consideration of the stresses upon them, and of the dimensions required for them, being left for Part IV., but it is necessary to note in this section one or two points of an elementary and practical character.

Sections of Cast-iron Girders and Cantilevers.—The use of cast-iron in girder construction is not at the present day considered advisable save for small and unimportant beams, while the expense of cast-steel precludes its adoption in building construction; but the student should be acquainted with the principles of design of cast-iron beams, and without going into particulars reserved for Part IV., enough must be said here to show what points have to be considered in determining the general form of a cast-iron beam, whether girder or cantilever.

Such beams consist of an upper flange, *u u*, Figs. 450, 451, and a lower flange (*l l*) joined by a web or vertical member (*w*).

Stresses on Flanges.—In the case of girders or bressummers supported at each end and loaded, either throughout, or at any point or points in their length, the upper flange is under compression tending to crush, the lower flange in tension, tending to

[1] A bressummer is a girder over a wide opening, and generally supporting a wall above it.

[2] A cantilever is a bearer, of which one end is fixed in the wall, the other end being unsupported.

tear across. This is illustrated in Fig. 448, where *c c c* denotes compression, and *t t t* tension.

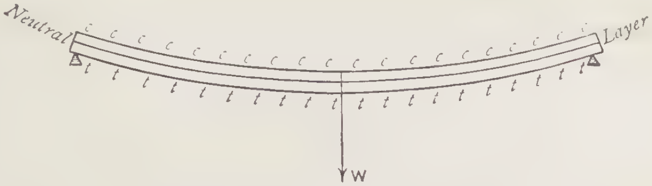


Fig. 448. *Beam or Girder loaded.*

In the case of cantilevers, the reverse takes place; loads on the cantilever cause the lower flange to be in compression and the upper flange in tension (see Fig. 449).

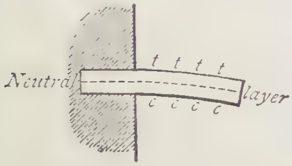


Fig. 449. *Cantilever loaded.*

The web need not be considered, as but little direct stress comes upon it in either case (see Part IV.)

Proportion of Flanges to resist Fracture.—It has been found by experiment that cast iron will generally be ruptured or torn asunder by a stress of 8 tons per square inch in tension, but that it requires as much as 48 tons per square inch to crush it under compression. In order therefore that the flanges may be of equal strength, so that one may not fail before the other, the tension flange should contain six times as many square inches to resist the tension upon it, as the compression flange contains to resist the crushing stress upon it.

This leads to a section like Fig. 450, for a girder, in which the lower flange (*ll*), being in tension, contains 36 square inches, and

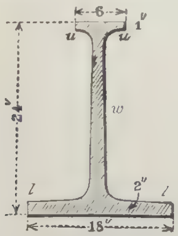


Fig. 450. *Cross Section of Cast-iron Girder.*

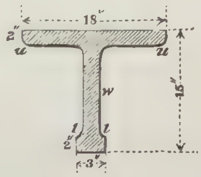


Fig. 451. *Cross Section of Cast-iron Cantilever.*

the upper flange (*uu*), under compression, contains only 6 square inches, so that the tension flange has 6 times the area of the compression flange.

In Fig. 451, the section for a cantilever, the upper flange is in tension and has six times the area of the lower flange.

Practical Proportion for Flanges.—The proportion of 6 to 1 for the area of the flanges is generally modified in practice according to circumstances.

The proportion of $\frac{1}{6}$ for the compression flange would lead in many cases to very small flanges in which a bubble or flaw in the casting would destroy a large proportion of the area, and therefore of the strength of the flange. Moreover, the compression flange requires to be stiff to prevent lateral bending, and in some cases room is required to rest the load upon it.

For these reasons and others of a theoretical character,[1] the area of the compression flange is often made about $\frac{1}{4}$ or even as much as $\frac{1}{3}$ of that of the tension flange.

Mr. Hurst says the area should be $\frac{1}{4\frac{1}{2}}$ when the load rests on the upper flange or on both sides of the bottom flange and $\frac{1}{3}$ if it rests on one side only.

Method of drawing the Cross Section of Cast-iron Girder.—With regard to the method of drawing a section in its right proportions, nothing can be more simple. The depth in case of a girder (generally about $\frac{1}{12}$ to $\frac{1}{10}$ the span) being known, and the size of the lower flange having been calculated, the upper flange is drawn so as to have $\frac{1}{4}$ to $\frac{1}{6}$ the area of the lower flange. This is for a girder or bressummer; for a cantilever the flanges are reversed.

For example, in the girder whose central section is shown in Fig. 452, the depth given is 19 inches, the area of the lower flange 18 inches by an average of about $2\frac{1}{4}$ inches $= 40$ inches, the area of the upper flange should therefore be $\frac{1}{4}$ of 40 inches $= 10$ inches. The upper flange is now drawn 6 inches wide and $1\frac{1}{2}$ inches thick at the ends, but averaging about $1\frac{3}{4}$ inches thick, so that its area is $6 \times 1\frac{3}{4}$ inches $=$ about 10 inches. The web is gradually tapered, its thickness at the bottom being equal to that of the lower flange, and at the top equal to that of the upper flange, so that there are no sudden changes in the thickness of the metal, which would lead to unequal contraction while cooling, and consequent rupture at the junctions of the unequal parts. For the same

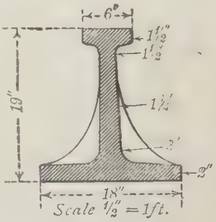


Fig. 452.

[1] See Part IV.

reason both the flanges and the web are often made of the same thickness throughout, as in Figs. 451, 453. The method of calculating the strength of girders, their shape in longitudinal section and plan, and other points connected with their construction, will be described in Part IV.

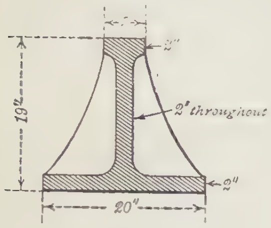


Fig. 453.

Elevations of Cast-iron Girders and Cast-iron Cantilevers.

A girder supported at the ends and uniformly loaded throughout its length, if it is to be of equal strength throughout, requires a section of larger area at the centre than at any other point. The section may be gradually smaller and smaller as the ends are approached.

The reason for this is that the stresses upon the girder are greatest at the centre and diminish gradually towards the end. If it were made of equal section throughout the girder would be unnecessarily strong except at the centre, and material would be wasted so far as the strength is concerned. This may, however, sometimes be necessary in order to afford space for the loads.

There are two ways of effecting the reduction of material.

a. Girder of uniform strength and uniform width.—The material may be reduced from centre to ends by reducing the depth of the girder, leaving the flanges the same width throughout as in Fig. 455. This is the most common form, and is convenient when anything is to rest upon the lower flange.[1]

Figs. 454, 455, 456 are the elevation, plan, and cross section at centre of a cast-iron girder of uniform strength, of which the section is varied by reducing the depth.[1]

b. Girder of uniform strength and uniform depth.—The width of the flanges may be reduced from the centre of the girder to the ends, leaving the depth the same throughout.

Figs. 457, 458 are the elevation and plan of a cast-iron girder of uniform depth in which the section is reduced towards the ends by gradually narrowing the flanges.[2]

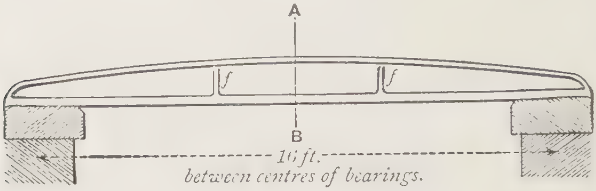
Girder with Feathers.—Sometimes ribs or "feathers" are cast upon the web of the girder, as at *ff* in Fig. 454, as stiffeners to

[1] The curve of the upper flange of a cast-iron girder of uniform width, uniformly loaded throughout its length, is theoretically nearly a parabola (something between an ellipse and a parabola), but practically a circular arc is used and the depth of the ends of the girder is made half that at its centre.

[2] The curves of the sides of the flanges in plan are parabolas.

strengthen it. They are, however, troublesome to cast, and tend to cause an objectionable stress upon the casting (see Part III.) at the angles where they join the girder. This is to some extent

Fig. 454. *Elevation.*



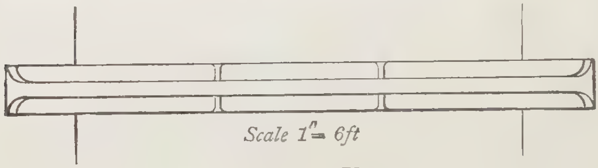
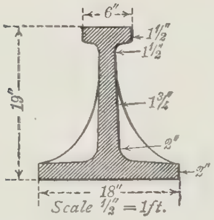


Fig. 455. *Plan.*

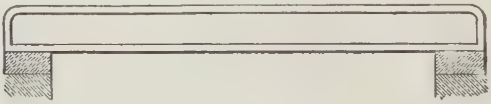


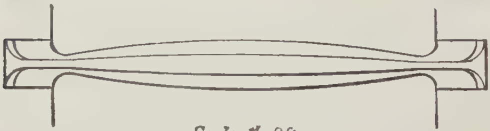
For alternative section of the same thickness throughout, see Fig. 453, p. 247.

Fig. 456. *Cross Section at Centre.*
Cast-iron Girder of Uniform Strength and Uniform Width.

avoided by stopping the feathers short of the top flange, as in Figs. 454, 456. In Fig. 453 they are carried up to the top.

Fig. 457. *Elevation.*





Scale 1" = 8ft.

Fig. 458. *Plan.*
Cast-iron Girder of Uniform Strength and Uniform Depth.

Practical Form for Cast-iron Girders.—It is sometimes incon-

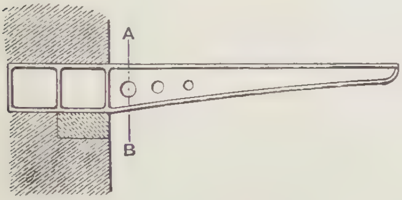
venient or impossible to use a cast-iron girder of uniform strength. For instance, when it has to carry weight on both flanges both are required to be horizontal and both to be of convenient width throughout.

Frequently, however, the load has to be carried entirely by the lower flange, and the girder may then be of varying depth as described at *a*, page 247.

Cast-iron Cantilevers.—In these, whether uniformly loaded throughout their length or loaded at the outer end, the stresses are greatest at the fixed end and diminish from that point to the outer end of the cantilever, which may therefore be graduated in depth.

Figs. 459, 460 are the elevation and plan of a cast-iron cantilever, of which Fig. 461 is the cross section at A B.[1]

Fig. 459. *Elevation.*



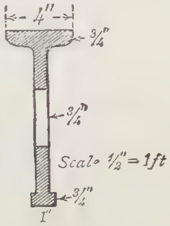
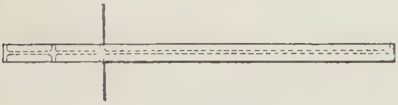


Fig. 461.
Section on A B, Fig. 459.



Scale 1/4" = 1 ft.

Fig. 460. *Plan.*

Cast-iron Cantilever.

Further Particulars relating to Cast-iron Girders.

The webs of both girders and cantilevers have only shearing stress to bear (see Part IV.) which is comparatively slight. They may therefore safely be lightened by piercing the web with holes as in Fig. 459. Perforated webs are, however, liable to unequal cooling and air bubbles, and should therefore be avoided where heavy loads have to be borne.[2]

Cast-iron girders should never be fixed at the ends nor be continuous over more than one span, for this would subject parts of

1 The theoretical curve of the lower flange of a cast-iron cantilever, uniformly loaded throughout its length, is nearly a concave parabola, practically a circular arc may be used.

2 Wray.

the small compression flange to tension, for which it would be quite unsuited.

The metal of cast-iron girders and cantilevers should, as explained above, be of equal or gradually varying thickness and the re-entering angles all rounded so as to avoid any internal stress (see Part III.) The thickness of metal in any part of cast-iron beams should as a rule not be less than $\frac{1}{12}$ of the width of the part.[1] The web should be equal in thickness to the flanges, tapering, where they differ, from the thinner to the thicker. Some engineers use, however, thinner metal when necessary.

So far as the requirements of good casting go, "for flanges 2 feet wide it is not wise to have a less thickness than $1\frac{1}{2}$ inches, and for flanges 18 inches wide not less than 1 inch, while for narrower flanges a somewhat less thickness may be used, although it is not a good plan to fine down the metal too much."[2]

The depth of cast-iron girders should be ordinarily from $\frac{1}{10}$ to $\frac{1}{12}$ the span. Sometimes even $\frac{1}{20}$ has been used, and cast iron should not be used for girders of over 20 feet span, nor at all for important girders.

Cast-iron girders are bedded at their ends on tarred felt. The ends are sometimes widened so as to increase the bearing area.

Girders should have a camber or rise in the centre of their length of about $\frac{3}{4}$ inch per 10 feet of clear span,[1] so that there may be no danger of their drooping or sagging below the horizontal line.

Small cast-iron girders are sometimes made of ⊥ section; in which case the web should be of a good thickness, as the upper portion of it has, in the absence of a top flange, to withstand considerable compression.

Objections to cast-iron girders.—Cast iron is easily moulded to girders of any ornamental pattern, and to any dimensions required to fit particular positions; but girders of this material are very heavy, are liable to contain dangerous flaws, are brittle and apt to break without warning, especially when cooled suddenly by water thrown upon them while they are very hot.

This is very likely to happen in a building on fire, and to cause serious accidents.

Cast-iron girders are heavier and less handy than mild-steel girders of equal strength, and are of much less reliable material. Cast iron is, however, useful when a girder or cantilever is required

[1] Adams. [2] Wray.

to be ornamental or of peculiar form—but as a material for girders generally it has been superseded by beams of mild steel, though it is still much used for small cantilevers, brackets, etc.

MILD-STEEL OR WROUGHT-IRON GIRDERS.

Rolled Beams of Steel or Iron.—The manufacture of rolled steel or iron beams or joists has been so much improved of late years that they can now be rolled to any size that is likely to be required in ordinary buildings.

Fig. 462. *Rolled Beam.*

In section (see Fig. 462) they somewhat resemble girders made of cast iron, except that both flanges are of the same size.

Rolled beams may ordinarily be obtained of various sections, from 3 to 24 inches in depth, with flanges of varying widths not usually exceeding 8 inches; but for a greater depth than 15 inches a built-up girder, such as one of those described below, is usually preferable.

The reason for this is that the number and thickness of the plates used in a built-up girder may be varied at different parts of it, in proportion to the stresses which come upon those parts; whereas, in a rolled girder, the thickness of the web and of the flanges is necessarily unvarying throughout, and if, therefore, these are thick enough to withstand the greater stresses, they are too thick in those portions where the smaller stresses occur.[1]

Compound Steel or Iron Girders.—Sometimes two or three steel or iron beams are riveted together with or without plates attached to them (see Figs. 463, 464).

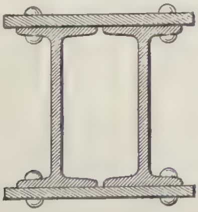


Fig. 463.

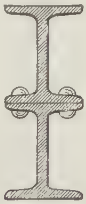


Fig. 464.

Compound Steel or Iron Girders.

Plate Girders.—If for any particular position rolled beams

[1] The theoretical advantage of the built-up girder may, however, be outweighed by the difference in cost between the riveted and the rolled section.

cannot be obtained of the necessary form or dimensions, girders may be built up by riveting plates and angle irons together in different ways.

Riveted, or, as they are more usually called, plate girders may be constructed of sizes far exceeding those of the largest rolled beams.

The best depth for these girders is about $\frac{1}{12}$ the span.

The simplest form of plate girder consists of angle irons (*ff*),[1]

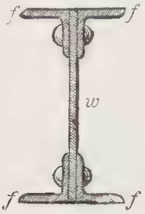


Fig. 465. *Section.*

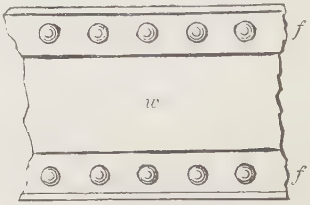


Fig. 466. *Elevation.*

Plate Girder.

riveted to a vertical plate (*w*), as shown in Fig. 465, the former being the flanges[2] and the latter the web of the resulting girder. The rivets are generally at a *pitch* (or distance between centres) of from 3 to 5 inches—most frequently 4 inches.

Some particulars regarding riveting are given at page 259. In some cases the rivets of the lower or tension flange of the girder are pitched at wider intervals than those in the upper or compression flange.

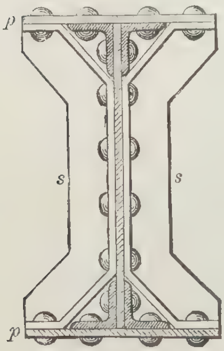


Fig. 467. *Section.*

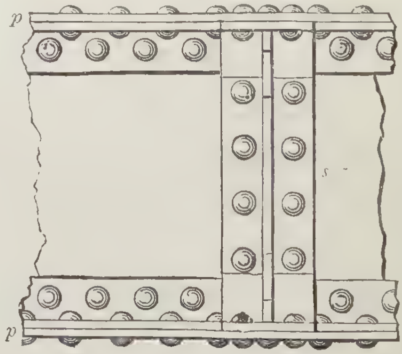


Fig. 468. *Elevation.*

Plate Girder.

In larger girders separate plates *p p* may be used for the flanges, and are fixed to the web by angle irons riveted as shown in Figs. 467, 468.

[1] Called "angle steels" in steel girders. [2] Called also "*booms*" in large girders.

When the web is deep, or of slight thickness, it has a tendency to buckle sideways, and requires support.

This may be afforded by stiffeners (*s*) of T iron[1] riveted vertically to both sides of the web along the girder, at distances varying according to the load, depth of girder, and thickness of web.

Extra stiffeners are also placed under points where heavy loads are expected.

The stiffeners may either be bent outwards at an angle as shown, or they may be cranked or joggled, that is bent close round, over the angle irons of the girder (which latter is a more expensive arrangement), or they may be kept out by means of distance pieces placed under them so as to clear the angle irons. This last arrangement is simple, but adds unnecessary weight to the girder.

In girders to carry great loads several plates are required in each flange, and when the flange-plates are wide, gussets or vertical plates are added; but such heavy girders are not likely to be required in any ordinary building.

"There are in existence plate-girder bridges of almost all possible dimensions, and some of the largest are objects of universal admiration; yet it may be broadly stated that the plate girder, if made beyond a span of 50 feet, loses those advantages which, up to that span, its simplicity affords as against the lightness of other systems."[2]

Box Girders are made up of plates united by angle irons and rivets into a hollow rectangular box section, as shown in Fig. 469.

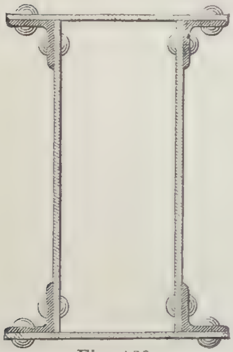


Fig. 469.
Section of Box Girder.

Box girders should be large enough to admit a man or boy, so that they can be painted periodically on the inside to prevent corrosion.

When the girder is necessarily too small to allow of this, the plates are made of extra thickness to allow for corrosion; and sometimes the interior of the girder is filled with concrete to protect the iron from the action of the air and to prevent oxidation.

Comparison of Plate and Box Girders.[3]—The comparative advantages of plate and box girders are summed up by Sir W. Fairbairn as follows:—"On comparing the strengths

[1] Called "T steels" in steel girders. [2] *Works in Iron*, by Ewing Matheson.

[3] Sir W. Fairbairn, *On the Application of Cast and Wrought Iron to Building Purposes.*

of these separate beams, weight for weight, it will be found that the box beam is as 1 : ·93, or nearly as 100 : 90.

"This difference in the resisting power of the two beams does not arise from any difference or excess in the quantity of material in either structure, but from the better sectional form of the box beam. The box beam, it will be observed, contains a larger exterior sectional area, and is consequently stiffer and better calculated to resist lateral strain, in which direction the plate form generally yields before its other resisting powers of tension and compression can be brought fully into action.

"Taking this beam, however, in a position similar to that in which it is used for supporting the arches of fireproof buildings, or the roadway of a bridge, when its vertical position is maintained, its strength is very nearly equal to that of the box beam.

"But while the plate beam, in the position thus described, is nearly equal, if not in some respects superior, to the box beam, it is of more simple construction, less expensive, and more durable, from the circumstance that the vertical plate is thicker than the side-plates of the box beam, and is consequently better calculated to resist those atmospheric changes, which in this climate have so great an influence upon the durability of the metals.

"Besides it admits of easy access to all its parts for purposes of cleaning, painting, etc."

Securing the ends of Girders.

It has already been mentioned that the ends of iron girders, especially those of cast iron, must not be rigidly *fixed* unless they have been designed as girders to be fixed at the ends, for otherwise stresses will come upon them which they were not designed to bear.

The ends of girders resting upon walls should be supported by hard stone templates, and may be bedded upon sheet lead or upon two thicknesses of asphalted or tarred felt, and if they are required to afford a tie to the structure, they may be secured by a bolt in a similar manner to the roof in Fig. 532.

Girders of over 50 feet span should have cast-iron shoes upon the ends so that they may slide when the girder alters length under changes of temperature, and large girders should have one end supported by rollers under a casting.

When the ends of girders meet over columns or piers they should be connected as shown in the Figs. below.

Fig. 470 shows two plate girders meeting over the head of a column, on which is a special casting leading to the floor above, through which casting the ends of the girders are connected by bolts as shown.

A rolled cross girder resting upon the lower flange of the main girder may be secured by a piece of angle iron, as in Fig. 471.

When, however, the level of the floor or other reason requires that the cross girder should be higher, it may rest upon the top flange of the main girder, when it may meet another cross girder running in the same direction and be connected to it by two flat plates on the web, as in Fig. 472.

When the cross girders are shallower than the main girder

Fig. 472.

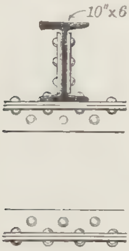


Fig. 470.

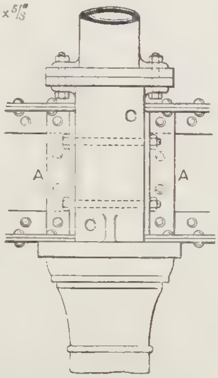
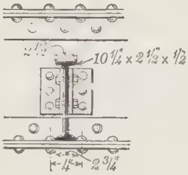


Fig. 471.



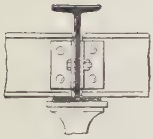


Fig. 473.

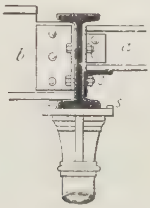


Fig. 474.

they may be connected, as in Fig. 473, or if the construction of the plan requires that they should be higher, they may be supported upon an angle iron bracket, as in Fig. 474, *a*.

If the cross girders are of the same height as the main girder they may be connected, as in Fig. 474, *b*.

As a rule girders should be connected by the webs, not the flanges. The latter arrangement would often be inconvenient, and would in many cases be equivalent to fixing the ends, or making the girders continuous, which would be objectionable.

When possible, the holes for bolts, etc., should be made as near

as possible to the neutral axis or centre line of the girder, so that they may be clear of the direct stresses upon it.

Further Particulars regarding Steel or Iron Girders.

The depth of plate girders varies from $\frac{1}{10}$ to $\frac{1}{15}$ the span; $\frac{1}{12}$ is said to be the most economical proportion.

The width of the flange under compression should not be less than $\frac{1}{30}$ to $\frac{1}{40}$ of the span, or it will be liable to buckle sideways. Both flanges must be wide enough for the rivets and for the ends of stiffeners where they are used (see Fig. 467).

No plates of less than $\frac{1}{4}$ inch thickness should be used, or they will soon be destroyed by corrosion.[1]

There should be as few joints as possible, especially in the tension flange and web.

Care should be taken to use standard sizes of plates and angle irons (see Part III.) as far as possible. For example, the web in small girders should where possible "be made an even multiple of 2 inches in order that market widths of plates may be used, to avoid the extra cost of shearing."[2]

Angle irons should not be specified of peculiar size and thickness exactly to suit the calculated dimensions, or the difficulty in fitting them will cause not only expense but delay. Expense is incurred by using extra sizes. It may, however, be cheaper in some cases to use extra lengths, in order to reduce the number of joints.

All parts should be so arranged as to be got at easily for riveting, and for periodical painting.

Plate girders should be constructed with a camber of about $\frac{1}{240}$ to $\frac{1}{480}$ of the clear span, so that when loaded they may not sag or appear to do so, and their ends should be bedded on lead or felt.

Plate III. Contract Drawing of Plate Girder, etc., to support Floor.

Figs. 475 to 478, Plate III., are reduced copies of the actual contract drawings for a girder to support a floor recently erected for a workshop in which heavy machines are used.

A plate girder of 35 feet span, a part elevation of which is shown in Fig. 475, supports rolled joists 6 feet 10 inches apart; upon these rest the timber joists carrying the wooden floor.

At the point where the cross section on A B, Fig. 476, is taken, there are three plates in each flange. A joint occurs near this point, and the ends of the

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[1] In many situations $\frac{3}{8}$ inch is a desirable minimum. [2] Adams.

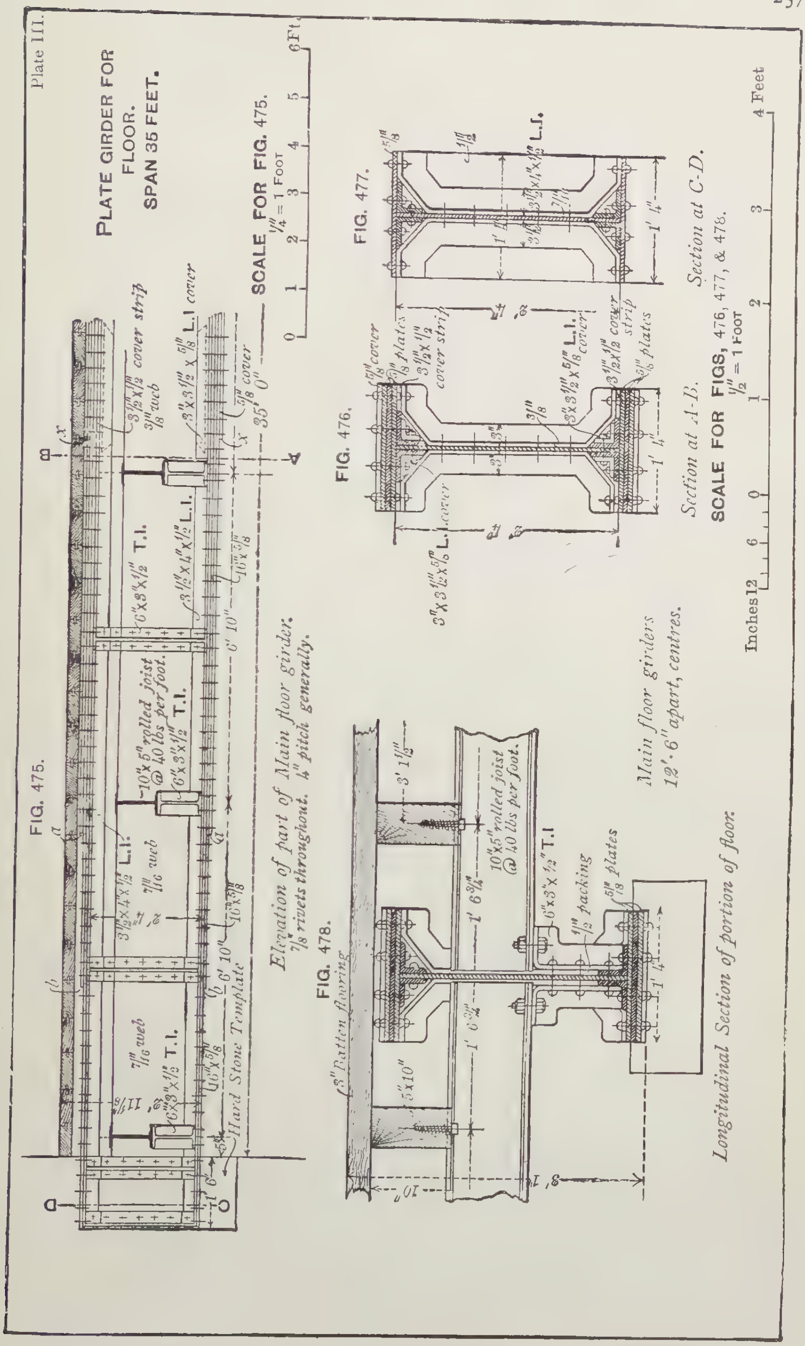


Plate III.
PLATE GIRDER FOR FLOOR. SPAN 35 FEET.
SCALE FOR FIG. 475.
FIG. 475.
FIG. 476.
FIG. 477.
FIG. 478.
Elevation of part of Main floor girder.
7/8" rivets throughout. 4" pitch generally.
Hard Stone Template
10"x5" rolled joist @ 40 lbs per foot.
Section at A-B.
Section at C-D.
SCALE FOR FIGS. 476, 477, & 478.
Main floor girders 12'·6" apart, centres.
3" Batten flooring
Longitudinal Section of portion of floor.

cover plates at *xx*, and of the cover strips and angle iron covers for this joint, are seen in elevation.

From *a* to *b* (in which portion the stress is less than in the centre of the girder) there are only two plates ; and from *b* to the end of the girder, in which portion the stress is still less, there is only one plate, as shown in the section, Fig. 477, taken through CD.

It will be seen that the positions of the rivets are shown in section by their centre lines and in elevation by intersecting lines showing their centres. The calculations for a girder of this type, and the methods by which the length and thickness of plates and covers are found, cannot be given here, but are described in Part IV. Some of the leading features in the design of this floor may, however, be briefly considered.

The distance of 12′ 6″ centres of main girders was determined by the spacing of the piers in main walls, the heavy loads carried by these girders being thus brought upon the most substantial portions of the wall.

The rolled joists are then spaced so as to conveniently subdivide the total span into five bays of 6′ 10″, while the timber joists 10″ × 5″, and 3″ planking are arranged as shown in Plate 2, ensuring stiffness under concentrated loads. In order to reduce as far as possible the total depth of floor, the rolled joists are placed at such a level that the 3″ flooring just clears the rivet heads in the upper flange of main girder. Fig. 478.

The main girders were designed to carry a distributed load of 3 cwt. per square foot of floor area, inclusive of the weight of the floor itself. They were tested under a central load of 40 tons, and their deflection under this load was $\frac{13}{32}$″ at the centre. The girders and rolled joists in this floor were of wrought iron. They would now be constructed of mild steel, the greater uniformity in quality of this material, combined with its superior strength and elasticity, having caused it to supersede wrought iron almost entirely. A description of the qualities and tests of steel of a class suitable for work of this kind will be found in Part III. Chapter IV.

Steel Skeleton Construction.—Among the most recent examples of the application of mild steel to building purposes may be noted the so-called "skeleton construction" as exemplified in some of the principal cities of the United States. Numerous buildings have been erected upon this principle, of 15 to 20 stories, and sometimes exceeding 250 feet in height, which are mainly dependent for their stability upon the combination of columns and girders which forms the "skeleton" framework, the exterior walling being frequently merely a veneer of terra cotta, brickwork, or stonework, anchored to, and carried by, the metallic framework.

Apart from any arguments for or against structures of this height and construction, based either on purely architectural or general grounds, the student will find much that is worthy of his careful attention in this application of mild steel, either as regards the sections of columns used, their connections to floor girders, the construction of heavy trusses on a large scale, the wind bracing, or the various systems of fire-proofing adopted. The same material is also found in the use of rails or rolled beams in the platform foundations, by means of which concentrated loads are distributed over soft and compressible soils. This subject cannot, however, be further considered here.

Chapter XVI.

RIVETING.[1]

RIVETS are small fastenings made of the best wrought iron or mild steel either by hand or by machinery, and before they are fixed consist each (see Fig. 479) of a small spindle or shank surmounted by a head, which may be pan-shaped as in Fig. 481, or formed like a cup or button as in Fig. 480.


Fig. 479.

About half of the shank of the rivet farthest from the head is slightly tapered.

When the rivet has been made red-hot, and put through the hole it is to occupy, the tail end of the shank is formed into a button or point of the shape required, which differs in the various kinds of rivets, as described at page 262.

Rivets are chiefly used to connect plates of iron. They are preferable to small bolts, because, being hammered close to the face of the plate, they hold more tightly, and the shanks of rivets are not so likely to become oxidised as those of bolts; moreover, as rivets are nearly always fixed when hot, they contract in cooling, and draw the plates together with great force.

They are much used in connection with building for uniting the parts of plate-web and braced girders, also for mild steel tanks and boilers.

Hand-riveting.—The actual handiwork connected with different processes in building has not, as a rule, been described in these Notes, because they can generally be seen by the student, and thus better understood than by any written description,—but with riveting the case is different. A student connected with ordinary building work is in many instances not likely to see riveting actually going on, and some knowledge of the process is necessary in order to understand the precautions which should be observed in good work.

The process of hand-riveting will therefore be briefly described.

A riveting gang consists of three men and two boys. The latter heat the rivets; the men insert and clench them.

The heating is generally effected in a portable smith's forge by

[1] The subject of riveting has been here introduced, as it is desirable that the student should possess some knowledge of this detail of construction in connection with riveted girders and roof work.

placing a few rivets in a plate bored with holes, so that their tails stick through the holes into the heart of the fire, while their heads upon the upper side of the plate are comparatively cool.

When the men require a rivet, the hottest is selected and handed to them by means of pincers.

Of the three men, two, the "riveters," stand on one side of the plate, and the third, the "holder-up," on the other side.

The riveters are armed with riveting hammers, two or three tapering steel punches, an iron "*snap*," *i.e.* a short bar having its end hollowed out to form a cup that will fit the point (when finished) of the rivet, and a heavy sledge-hammer with which to strike this snap, called a "cupping hammer."

The holder-up has a heavy bar, or holding-up iron, the end of which is also hollowed out to fit the rivet head, or a heavy hammer fitted upon a long stave may be used for the purpose.

The operation is as follows.—The riveters drive a punch through the holes for the rivet about to be inserted, so as to make those in the several plates coincide with one another.

The holder-up knocks the punch back out of the hole, picks up a red-hot rivet and places it in the hole with its red-hot tail sticking out toward the riveters, and places his iron upon its head.

The riveters then hammer the iron immediately round the rivet, so as to bring the plates close together. If this is not done, the rivet, when hammered, will bulge out between the plates, and keep them apart.

They then hammer down the tail of the rivet neatly, so as to form a point of the shape required.

This last operation should be performed with heavy hammers having flat ends; and by it not only should the end of the rivet be formed, but the whole shank should be "upset," that is, squeezed up and made thicker, so as to fill the hole completely.

When the rivet is to be formed with a convex point, it is generally finished with the snap.

After the point has been neatly formed by the hammers, and is just losing its red heat, the snap is held upon it by one of the riveters, and struck by the other with the cupping hammer (the holder-up pressing his hammer against the head of the rivet on the other side), so that the point formed is made smooth and even, and all superfluous metal round the edges is cut off.

Machine-riveting is done with rivets of the same form as those clenched by hand,—generally with snap heads and points. The

rivets are inserted red-hot, and the points clenched by means of a die which moves forward and squeezes it into shape under steady and severe pressure, as in the case of hydraulic and some forms of pneumatic riveters, or by a series of very rapid blows delivered by means of pneumatic hand-hammers working under an atmospheric pressure of 90 to 100 lbs. per square inch.

Such apparatus is used not only in the maker's yard, but is also employed in riveting work *in situ*, or, as it is termed, in *field* riveting, when the local conditions are favourable to its employment.

Comparison of Machine and Hand-riveting.—Machine-riveting is cheaper and better than that done by hand. The steady pressure brought by the machine upon the rivet not only forms the head, but compresses and enlarges the shank, so that it is squeezed into, and thoroughly fills up all the irregularities of the holes.

The superiority of machine-riveting is strikingly shown when rivets have to be taken out.

After the head is cut off, a hand-clenched rivet may be easily driven out, but a machine-clenched rivet must, as a rule, be *drilled* out.

Rivets clenched by machines can generally be easily distinguished from those done by hand; the latter are covered with marks caused by the shifting of the snap during riveting; while on a machine-riveted head there is generally a burr like the peak of a jockey's cap, caused by the die having caught the rivet a little out of the centre.

Cold riveting.—Very small rivets for boiler work or in positions where it would be impossible to heat them may be clenched cold. The process is a quick one, but the iron used must be of very superior quality.

Caulking is a process adopted when it is necessary to render the joints to be connected water-tight, as in the case of tanks or boilers.

This process consists in knocking down the edges of the plates with a blunt steel caulking tool, so as to bring the edges together and to close the opening. In the case of rivets, the edges of the head or point are beaten down until they indent and slightly penetrate the surface of the plates, and thus completely close the opening. Pneumatic caulkers are often used for this purpose.

Different Forms of Rivets.—There are various names given to rivets, according to the shape to which the point is formed.

Snap rivets are those of which the points formed while the iron is hot are finished with a tool containing a nearly hemispherical hollow, which shapes it as shown in Fig. 480.

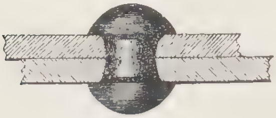


Fig. 480.

That figure represents a snap rivet in a punched hole. This form of rivet is very frequently used in the best girder work.

Button or cup-ended rivets.—These are names sometimes applied to snap rivets.

Hammered rivets have points finished, by hammering only, to a conical form as in Fig. 481, which shows such a rivet in a drilled hole.

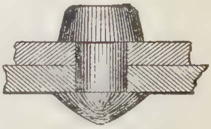


Fig. 481.

They are more liable to leak than those with button points, but are used for rivets of large size, which, if finished with snap points, would require very large hammers in order that the points might be beaten down quickly enough.

Rivets with conical points are sometimes called *staff rivets.*

The rivet in Fig. 481 has a *pan head,* a modification of it in which the sides of the head are vertical is called a *cheese head,* and shown in Fig. 482.

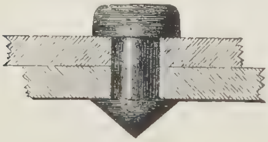


Fig. 482.

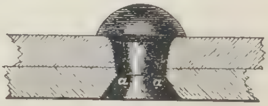


Fig. 483.

Countersunk rivets are those in which the point is hammered down while hot flush with the surface of the plate, as in Fig. 483.

This is necessary wherever a smooth surface is required, free from the projection that would be caused by ordinary rivet heads.

The countersinking is drilled, and may extend right through the plate.

It is frequently the practice, however, to have a shoulder at the upper edge of the lower plate, as shown at *a a*, so that the countersink does not extend right through the plates.

The sides of the countersunk portion may be directed upon the centre of the rivet hole at the edge of the plate, as in

Fig. 483, or in many cases they are not inclined so much as shown.

STEEL RIVETS require very careful treatment or their heads will be apt to fly off upon receiving a sudden jar if made of too hard a quality of steel. They should be of mild steel, of low carbon content, and with a high percentage of extension. Rivets of this quality offer no special difficulties in construction.

Proportions of Rivets.—The aggregate section of the rivets in any joint must be determined by the stress that will come upon them, but the diameter of the individual rivets in punched holes will depend upon the thickness of the plates through which they pass; for in punching holes it is advisable, in order to avoid breaking the punch, that its diameter should be greater than the thickness of the plate.

Sir William Fairbairn's rules for the proper diameters for rivets passing through punched holes in plates are as follows:—

For plates less than $\frac{1}{2}$ inch thick the diameter of the rivet should be about double the thickness of the plate.

For $\frac{1}{2}$ inch and thicker plates the diameter of the rivet should be about $1\frac{1}{2}$ time the thickness of the plate.

When holes are *drilled* they may be smaller in proportion to the thickness of the plate.

When plates of different thicknesses are joined, the rivet is proportioned with reference to the thickest of the plates.

Professor Unwin's rule for the diameter of rivets joining plates is as follows:—

$$d = 1 \cdot 2\sqrt{t}.$$

Where d is the diameter of the rivet and t the thickness of the plate.

The hole is generally practically from 4 to 20 per cent of the diameter larger than the cold rivet, which will more than allow for the expansion of the latter when heated before insertion.

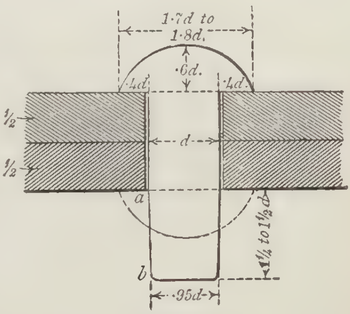


Fig. 484.

DIMENSIONS OF RIVET HEADS, ETC.—*The height of the head of a snap rivet* should be about $\frac{2}{3}$ of the diameter of the shank, and the diameter of the head should be from $1\frac{1}{2}$ time to twice that of the shank.

The length of the rivet before clenching, measuring from the head = sum of thicknesses of plates to be united + $1\frac{1}{4}$ to $1\frac{1}{2}$ time the diameter of the rivet (see Fig. 484). For machine-riveting, $a\,b$ should be made $\frac{1}{8}''$ to $\frac{1}{4}''$ longer.

Pitch of Rivets.—The "*pitch*" of rivets is their distance from centre to centre.

This distance varies according to the nature of the stress upon the joint and with the number of rivets necessary to be inserted in a given space.

The pitch used for girder work varies from 3 to 5 inches, but it should not exceed 10 to 12 times the thickness of a single plate, as otherwise damp may get in between the plates and cause rust, which in time swells and bursts them asunder.[1]

The proportions for heads of different forms are as follows (see Figs. 480-483).

	Height.	Width of base of head.	Length of $a\,b$, Fig. 211.
Conical heads	·75 *d.*	2 *d.*	1·2 *d* to 1·5 *d.*
Pan heads	·7 *d.*	1·6 *d.*	not formed by riveter
		1·45 *d.* top of head	
Cheese head	·45 *d.*	1·5 *d.*	,,
Countersunk	·4 *d* to ·5 *d*	1·5 *d* to 1·6 *d.*	·75 *d* to 1 *d.*

Where a number of plates have to be joined, $\frac{1}{32}$ inch for each plate is added to *a b.*

The above are general dimensions, but some engineers provide a special drawing of the rivet head they require.

The distance between the edges of rivet holes, to prevent the danger of breaking two into one, should not be less than equal to the diameter of the rivets. This, it will be seen, leads to the rule that the minimum pitch of rivets should not be less than twice their diameter.

The distance between the edge of a rivet hole and the edge of the plate in which it is formed, to prevent it tearing through, should not be less than the diameter of the rivet. Thus the *centre* of the rivet will be $1\frac{1}{2}$ diameters from the edge of the plate. Sometimes for thick plates $\frac{1}{16}''$ or $\frac{1}{8}''$ is added to the distance.

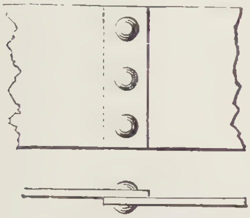
RIVETED JOINTS.

Lap Joints are formed by riveting together plates that overlap one another, as in Figs. 485-488.

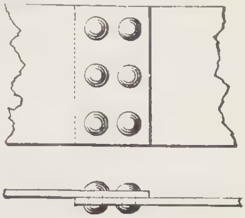
The overlap should not be less than $3\frac{1}{4}$ to $3\frac{1}{2}$ times the diameter of the rivets in single riveting (Fig. 485), or $5\frac{1}{2}$ to 6 diameters in double riveting (Fig. 487).

[1] Stoney.

There are formulæ[1] for finding the length of the overlaps, so that the joints may be of equal strength throughout; but the above rules will be a sufficient guide in ordinary cases.



Figs. 485, 486.
Lap Joint single riveted.



Figs. 487, 488.
Lap Joint double riveted.

FISH JOINTS are those in which the ends of the plates meet one another, the joint being "fished" either with a single "cover plate," as in Fig. 490, or with one on each side, as in Fig. 491.

When a single cover plate is used it should be of somewhat greater thickness than that of either of the main plates to be united, in order to allow for the extra stress caused by the cover plate being out of the direct line of stress (see Part IV.)

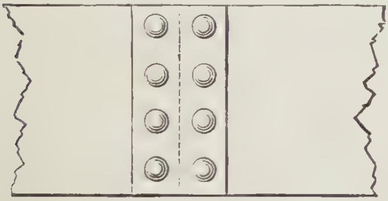


Fig. 489. *Plan of Fish Joint.*

Fig. 490. *Section of Fish Joint, one Cover Plate.*

Fig. 491. *Section of Fish Joint, two Cover Plates.*

When two cover plates are used each of them should be of not less thickness than half the thickness of either of the plates to be united.

BUTT JOINTS is the name given to fished joints that are in compression, so that the ends of the plates butt evenly against one another.

This seldom occurs in practice, for the very process of riveting draws the plates slightly apart, and the edges are sometimes caulked to conceal the gap.

Sometimes the gap is filled with cast zinc run into the interval.

If, however, the plates are carefully planed square at the edges,

[1] See Part IV.

and brought very carefully into close contact throughout their width, the joint is called a "*jump joint.*"

SINGLE RIVETING consists of a single row of rivets uniting plates in any form of joint, as in Figs. 485, 486, 489, 490, 491.

DOUBLE RIVETING is that in which the plates are united by a double row of rivets, as in Figs. 487, 488, 492.

Double riveting may be either "*chain,*" as in Fig. 487, or "*zigzag,*" as in Fig. 492.

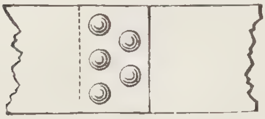


Fig. 492. *Zigzag Double Riveting.*

Fig. 493. *Chain Riveting.*

TRIPLE AND QUADRUPLE RIVETING are formed by 3 or 4 rows of riveting respectively.

CHAIN RIVETING is formed by lines of rivets in the direction of the stress, parallel to one another on each side of the joint, as in Fig. 493.

ZIGZAG RIVETING consists of lines of rivets so placed that the

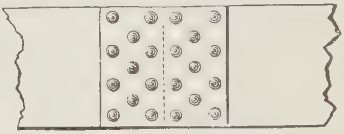


Fig. 494. *Zigzag Riveting.*

rivets in each line divide the spaces between the rivets in the adjacent lines, as in Figs. 492, 494.

Comparative Strength of different kinds of Riveted Joints.—The relative efficiency in tension of the different forms of joint, as compared with that of the solid plate, is stated by Mr. Stoney to be as follows for wrought iron[1]:—

	Efficiency per cent.
Original solid plate	100
Lap joint, single riveted, punched	45
,, ,, drilled	50
,, double riveted	60
Butt joint, single cover, single riveted	45-50
,, ,, double riveted	60
,, double cover, single riveted	55
,, ,, double riveted	66
Tension flanges of girders, triple or quadruple riveted	70-80

[1] Provided the joint is so designed as to be on the point of yielding from the tearing of the plates or shearing of the rivets indifferently.—*The Strength and Proportions of Riveted Joints*, p. 41.

Joints in Tension.—*Lap Joints.*—Fig. 495 shows the arrangement of rivets generally adopted for lap joints which are to undergo a tensile stress.

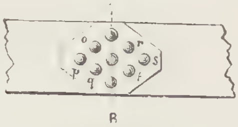


Fig. 495.

The object of so placing the rivets is to keep the strength of the joint as nearly equal to that of the original plate as possible.

In this case the strength of the joint may be arranged so as to be equal to that of the cross section of the plate, less one rivet hole.[1]

It is true that the weakest section of the plates themselves is at A B, where they are pierced by three rivet holes; but before either plate could break at this line, the three rivets, *opq* or *rst*, within the line must be shorn in two.

Thus, before the upper plate can tear at A B, *o p q* must be shorn; and before the lower plate can give way at AB, the rivets *r s t* must be shorn.[2]

This can be shown by figures as follows:—

Calculation.

Suppose the plates to be 8″ wide and $\frac{3}{8}$″ thick—joined by $\frac{3}{4}$″ rivets—and that the tensile strength of the iron is 20 tons per square inch, and its resistance to shearing 16 tons per square inch, then

A. If the joint could fail by one of the plates tearing across AB and shearing three rivets (either *opq* or *rst*), the under-mentioned resistance must be overcome.

Plate less 3 rivet holes $= (8'' - 3 \times \underset{\text{Rivets.}}{\tfrac{3}{4}}) \times \tfrac{3}{8}'' \times 20$ tons
$= 43{\cdot}1$ tons.

Shearing resistance 3 rivets $= \underbrace{\pi \times \frac{(\frac{3}{4})^2}{4}}_{\text{Shearing area of rivet.}} \times 3 \times 16$ tons
$= 21$ tons.

The total resistance will be $= (43{\cdot}1 + 21)$
$= 64{\cdot}1$ tons.

B. If the joint could fail by tearing a plate through rt or oq and shearing one rivet at s or p, the resistance would be

Plate less 2 rivet holes $= (8'' - 2 \times \tfrac{3}{4}) \times \tfrac{3}{8}'' \times 20$ tons
$= 48{\cdot}7$ tons.

Shearing resistance 1 rivet $= \frac{\pi \times (\frac{3}{4})^2}{4} \times 1 \times 16$ tons
$= 7$ tons.

Total resistance $= 55{\cdot}7$ tons

C. If the joint were to fail by the plate tearing across through s or p, the resistance to be overcome would be

Plate less 1 rivet hole $= (8'' - \tfrac{3}{4}) \times \tfrac{3}{8}'' \times 20$ tons
$= 54{\cdot}4$ tons.

Therefore, as the resistance through *s* or *p* is (as is shown at C above) less than the resistance at either of the other sections as shown at A or B, the joint will fail

---

[1] To ensure this, the loss of tensile strength in a plate caused by a rivet hole must not be greater than the shearing strength of a rivet.

[2] *Shearing.*—A rivet is shorn when by the sliding movement of one or both of the plates through which it passes it is cut through horizontally.

by tearing across through s or p—that is, it is equal to the strength of the plate less *one* rivet hole.

Again it has been suggested that the joint might fail

D. At the centre by the fracture of the two plates pierced by three rivet holes. This, however, is not the case.

The effective strength or resistance of the two plates would be

$$2 \text{ plates less } 3 \text{ rivet holes} = 2\ (8'' - 3 \times \tfrac{3}{4})\ \tfrac{3}{8}'' \times 20 \text{ tons}$$
$$= 86 \cdot 2 \text{ tons.}$$

This assumed section of rupture offers therefore more resistance than any of the others, and the joint cannot fail here.

Working Stress.—In practice the stress allowed upon the joint would be only $\frac{1}{4}$ of the breaking stress taken above, and the working stress allowed would therefore be $\frac{1}{4}$ of the weakest resistance

$$= \frac{54 \cdot 4}{4} = 13 \cdot 6 \text{ tons.}$$

BUTT JOINTS.—The same principle may be applied to a joint

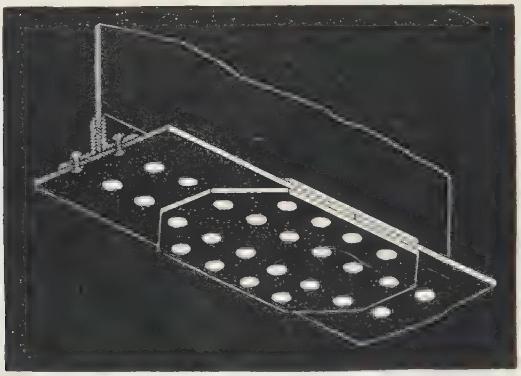


Fig. 496.

with cover plates, as shown in Fig. 496. The arrangement is similar to that in Fig. 495, but with two rivets at the weakest part.

The riveted joints of tension booms of girders are very commonly arranged in plan, as shown in Fig. 496.

Joints in Compression.— It was at one time thought that for a butt joint under compression very few rivets were necessary; that the whole strain was communicated by the end of one plate to the other upon which it pressed; and that the rivets would be required only to keep the plates in their places.

Experience has shown, however, that in practice we cannot depend upon the plates being so closely butted against one another as to transmit the thrust direct (see p. 265).

"Very slight inaccuracy of workmanship may cause the separation of the butting plates, and then the whole thrust is transmitted through the rivets and through the cover plates."

"For the best bridges it is now assumed that all the joints shall be of sufficient strength to take the whole strain, if necessary, through the rivets."

"The only way in which compression joints may safely differ from tension joints is, that the rivets may be more closely spaced across the plate, the quantity punched out in any section not affecting the strength of a compression joint as it does that of a tension joint."[1]

Grouped Joints.—The joints that occur in the plates of riveted girders are generally formed with cover plates.

When there are several layers of plates, as in the booms of a large girder, the joints may with advantage be collected into groups, so that several may be covered by one pair of plates, as shown in Fig. 497.

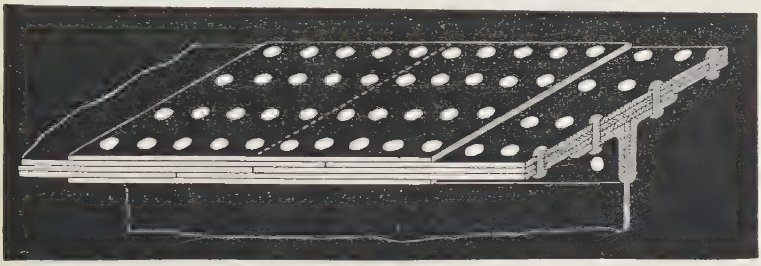


Fig. 497. *Grouped Joint.*

Fig. 497 shows the joints in the three plates of the boom of a heavy girder collected under cover plates. The joints may be chain or zigzag riveted in plan; or in some cases the cover plates are cut off obliquely, so as to have triangular ends, and the rivets are arranged somewhat as in Figs. 495, 496.

Essentials of Good Riveting.—RIVET HOLES.—The holes in plates to be riveted may be either punched or drilled.

In whichever way they are formed, it is important that they should be cut clean and true, and should fit exactly over one another. If they do not, an irregular cavity is formed, which has to be forcibly straightened by a steel pin or "drift punch" before the rivet is inserted, thus injuring the plate, enlarging the hole, and causing the rivet to fit loosely.

Some difference of opinion has existed as to whether punched or drilled holes make the best work.

Punched Holes.—The punched hole is slightly conical in shape; thus the rivet filling the hole in two plates is of a double conical shape. It is, of course, important that the hole should be punched so that the narrow part of the cone is on that side of each plate

[1] Unwin, *Iron Bridges and Roofs.*

which meets the other plate. Such rivets "have been known to hold the plates together even after the heads have been removed by corrosion."

This is a great advantage in shipbuilding and boilermaking, but in girder work rivets are seldom subject to a strain in direction of their length.

In practice the conical shape is often destroyed and its advantages lost by the insertion of the drift above referred to.

The process of punching is, however, not so accurate as drilling; it tears and injures the plate round the edges of the holes, especially when the iron is not of good quality.

Drilled Holes.—On the other hand, drilled holes may be accurately formed without the slightest injury to the plate, and of a diameter smaller than the thickness of the plate. When there are many plates to be united, so that multiple drills can be used, the cost is not greater than that of punched holes; and the advantage gained in the work coming together properly, and the rivet holes being fair, is very great.

The sharp edges of drilled holes have been found by experiment to expedite the shearing of the rivets. To prevent this the edges of the holes have in some cases been rounded, which has been found to increase the resistance of the rivet by about 10 per cent.[1]

Cases in which Drilled Holes and Punched Holes may respectively be used.—To sum up, we may say that in really first-class work, when several layers of plates have to be riveted together, when small scantlings are used as in some roofs, or when the rivet holes are of a diameter less than the thickness of the plates, it is desirable that the holes should be drilled.

Combined Punched and Drilled Work.—Excellent work is produced by the process of first punching the holes to such a diameter that the larger diameter of the punched hole is about $\frac{1}{8}$ inch less than that of the finished hole, and then drilling out the remainder of the metal. This process secures the advantages of drilled work at less cost, while the zone of metal stressed by the punching process is practically removed.

Heating.—Rivets should be heated uniformly throughout their whole substance; not raised above a dull red (by daylight); not twice heated.

The heating should be effected in an air furnace, the rivets being kept clear of the fuel.

[1] Sir William Fairbairn, *Proceedings of Royal Society*, 24th April 1873; but this process is not adopted in practical work.

An ordinary fire heats the rivets partially, and so quickly that they are frequently burnt.

The usual plan is to arrange the rivets in a flat plate full of holes, through which their tails protrude. This plate is placed upon the fire, and thus the tails become very hot—sometimes white hot—while the heads remain comparatively cool.

For riveting by hand, however, it is desirable that the head of the rivet should be even hotter than the point, otherwise the blows which are sufficient to expand the rivet and make it fill the hole near the point will not have so much effect at the other end, and the rivet will not quite fill the hole near the head.

It is of the utmost importance that rivets should not be overheated, otherwise the iron will lose its ductility, and the rivets will become weak and brittle.

If proper attention be not paid to this point, much injury may be done by too large a number of rivets being put into the fire at once to save trouble, and consequently left there too long.

Arrangement.—All rivets should be arranged in such positions that both ends can be got at during construction.

Causes of Failure.—Riveted joints are liable to fail in different ways, according to their form and the nature of the stress brought upon them.

Among the causes of failure are the following:—

The rivets themselves may fail by their heads being shorn off, by the pins being ruptured under a tensile stress (though rivets should, as a rule, be subjected only to shearing stress), or by the pins being cut in two by a shearing stress.

Any plate may fail either by the inability of its "effective section" (that is, the section of the plate left after the rivet holes are cut out) to resist the stress, or by the rivets shearing through the portion of plate beyond them. In some cases also, where the rivet has not sufficient bearing area, it indents and crushes the plate round the edge of the hole, or again the plate may indent and injure the rivet, and causes a loose joint.

For important work it is necessary carefully to calculate the stresses which will come upon a joint, and to arrange the number, size, and position of the rivets, their distances apart, and the dimensions of the plates accordingly. Such calculations are, however, beyond the limits of this volume, and will be entered upon in Part IV.[1]

[1] *Calculations for Building Structures*, Chap. VII.

Chapter XVII.

STEEL OR IRON ROOFS.[1]

THE variety of sections rolled in mild steel or iron now obtainable, together with the practical advantages in design afforded by the use of these materials, with the consequent greater certainty in the distribution of stresses, have caused the use of timber in roofs to be superseded to a great extent, especially in trusses of large span.

When iron was first employed in the construction of roofs, it was used only for those members of the ordinary timber trusses for which it was evidently better adapted than wood.

Some examples of these roofs in the transition state, composed of wood and iron combined, are given in pages 180 to 184.

In process of time iron was substituted, first for one member of the roof, then for another, until the whole truss was composed of iron in different forms.

The result of this gradual change was that the early iron roofs were nearly of the same form of construction as the ordinary timber trusses.

It was soon noticed, however, that the material could be better applied, and different forms were adopted for iron roofs, some of which will now be described.

Classification of Iron Roofs.—The various forms of iron roofs have been classed as follows :—[2]

1. Roofs with straight rafters.
2. Roofs with arched rafters.
3. Mixed roofs, which form a transition between the other two.

Of these, the second and third classes are used chiefly for very large spans, far exceeding those of 40 feet (to which this chapter is limited). It will, therefore, be unnecessary further to notice them, except in the case of two very simple examples of arched roofs, which may here be described before the whole of Classes 2 and 3 are dismissed as not coming within the scope of these notes.

[1] Wrought iron in roof work has been practically superseded by mild steel, but the details in these chapters referred to as being of wrought iron may without material error be considered to represent present practice in mild steel within the limits of span contemplated in this work. Tie rods of circular section are, however, frequently replaced by flat or angle sections with riveted connections, as in Plates VIII. and XVIII., whereby smith work in jaws and eyes is avoided.

[2] Unwin's *Wrought-iron Bridges and Roofs.*

Corrugated Iron Arched Roof.—This simple form of arched roof consists merely of sheets of corrugated iron riveted together into the form of an arch. The edges of the resulting large arched sheet are secured at the springing to wall plates, angle irons, or to the inner sides of iron gutters. Tie rods, king bolts, and struts are used for moderate spans and curved iron Principals for larger roofs.

Figs. 498, 499 show two forms of this kind of roof.

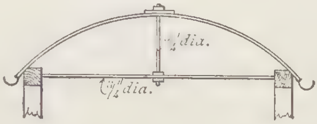


Fig. 498.

Up to 10 *feet span* a simple arched sheet of corrugated iron may be used; it is fixed at the eaves to timber wall plates by coach screws, and is like Fig. 498, but without the tie and king rod.

For spans of 12 *feet* the rods as shown in Fig. 498[1] are necessary (even for 10 feet spans they are desirable), and roofs of this form have been used for spans up to 30 feet. It is better, however, to restrict them to 20 feet.

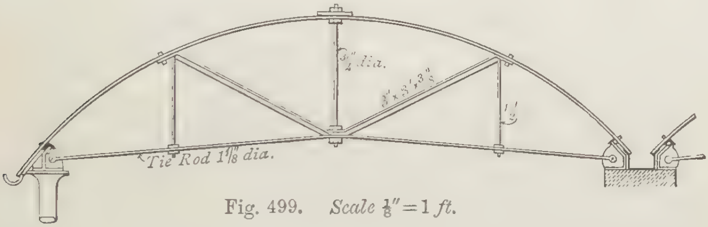


Fig. 499. *Scale* $\frac{1}{8}'' = 1$ *ft.*

For spans of over 20 *feet* struts must be added as shown in Fig. 499. The ends of the tie rod are secured to plates on the heads of the columns, or walls supporting the roof, or to cast-iron gutters made specially thick, and for the large spans, strengthened by flanges, and stiffened by arch-shaped cast-iron stays across them at intervals of about 10 feet, and the covering is fastened near the eaves by hook bolts to angle irons secured to the head of the columns. The covering and columns should be well held down, as the wind has a great effect upon roofs of this kind. Such roofs may be used up to spans of 30 or 35 feet, but beyond this curved Principals must be used with purlins to carry the roof covering. The corrugated iron may generally be of 18 to 20 Birmingham wire gauge, and the tie rods 8 feet apart.

[1] From Messrs. Rownson, Drew, and Co.'s catalogue.

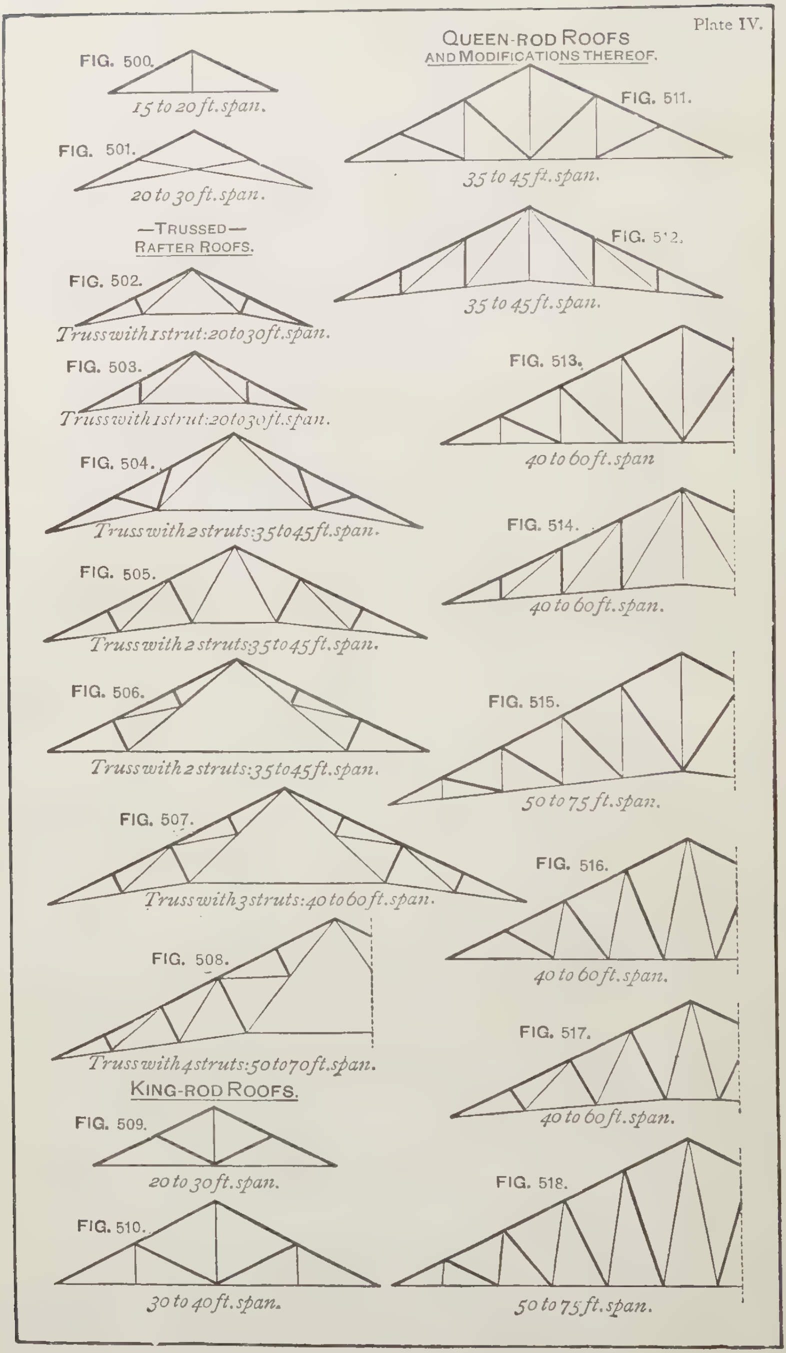


Plate IV.
QUEEN-ROD ROOFS AND MODIFICATIONS THEREOF.
FIG. 500.
15 to 20 ft. span.
FIG. 501.
20 to 30 ft. span.
FIG. 511.
35 to 45 ft. span.
—TRUSSED— RAFTER ROOFS.
FIG. 512.
35 to 45 ft. span.
FIG. 502.
Truss with 1 strut: 20 to 30 ft. span.
FIG. 503.
Truss with 1 strut: 20 to 30 ft. span.
FIG. 513.
40 to 60 ft. span
FIG. 504.
Truss with 2 struts: 35 to 45 ft. span.
FIG. 514.
40 to 60 ft. span.
FIG. 505.
Truss with 2 struts: 35 to 45 ft. span.
FIG. 506.
Truss with 2 struts: 35 to 45 ft. span.
FIG. 515.
50 to 75 ft. span.
FIG. 507.
Truss with 3 struts: 40 to 60 ft. span.
FIG. 516.
40 to 60 ft. span.
FIG. 508.
Truss with 4 struts: 50 to 70 ft. span.
FIG. 517.
40 to 60 ft. span.
KING-ROD ROOFS.
FIG. 509.
20 to 30 ft. span.
FIG. 518.
FIG. 510.
30 to 40 ft. span.
50 to 75 ft. span.

Forms for Iron Trusses.—It may be convenient to bring the different forms of trusses ordinarily used for iron roofs with straight rafters into one view before they are described in detail.

Figs. 500 to 518, Pl. IV., show forms of trusses, most of which are in common use, and the spans for which each is adapted.

When the principal rafters are long they require support at intermediate points, which with roofs of ordinary construction should not be more than 8 or 9 feet apart. This support may be given in two distinctly different ways.

Trussed Rafter Roofs.—In these the principal rafters are supported by one, two, or more struts at right angles or nearly at right angles to them, which together with tension rods form the principal rafters into a pair of trusses, joined at the ridge of the roof and prevented from spreading by the tie rod.

Sometimes, though rarely, the struts supporting the principal rafters are vertical as in Fig. 503.

King- and Queen-rod Roofs and modifications thereof.—In these the trusses are of the same skeleton form as in timber roofs, the principal rafters being supported by inclined struts which with the tension rods and tie rod form the whole into a truss.

Occasionally, however, though but rarely, the struts are made vertical and the tension rods inclined as in Figs. 512, 514. The vertical struts are more convenient when the roof has hipped ends.

ROOFS WITH STRAIGHT RAFTERS.

King-rod Roof, without Struts.—The simplest form of iron roof with straight rafters is shown in Fig. 519.

Fig. 519. *Scale* $\frac{1}{3}'' = 1\,ft.$

The rafters are of T iron, united at the apex by a pair of overlapping plates[1] riveted to both, and from which is suspended the king bolt, the head of which is forked, so as to pass on each side of and embrace the plate.

The tie rod is bolted to the lower end of the rafter, and is supported in the centre by a double nut at the foot of the king bolt. The lower end of the rafter is itself secured to the head of the column supporting the roof.

As the rafter is entirely without support, except at the ends, this form of roof is not adapted for spans greater than from 15 to 20 feet.

The roof, when fixed, may be tightened up by screwing the nut at the foot of the king bolt, so as to shorten the latter and raise the tie rod.

King-rod Roof, with Struts.—In the king-rod roof, shown in Fig. 520, the principal rafters are of T iron, the struts of angle

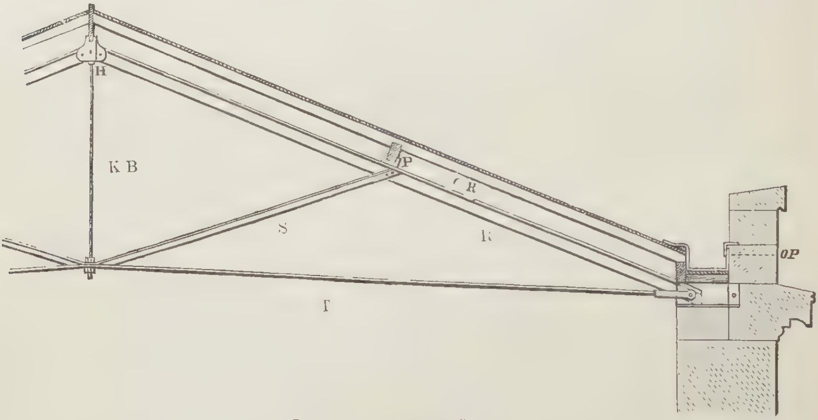


Fig. 520. *Scale* $\frac{1}{4}'' = 1$ *ft.*

iron, the common rafters and purlins of wood. The inclination of the struts is bad, being too oblique to the principal rafter to enable them to take the thrust properly. The king rod is of circular rod iron, fixed at the top into a cast-iron head, its lower end being furnished with a screw, which, passing through holes in the feet of the struts and in the centre of the tie rod, is secured by a nut.

The upper end of each principal rafter enters the cast-iron head, and is secured to it, while the lower end is fastened by a bolt (which passes also through the forked end of the tie rod) to an iron chair which is secured to the wall.

[1] Called *Cheek Plates* or *Gusset Plates.*

It will be seen that by screwing up the nut at the foot of the king bolt, the tie rod is raised and the roof tightened up.

Fig. 521 is a modification of the king-post roof constructed in iron. The dotted lines show additional suspending rods, which may be added in roofs of larger span, *i.e.* above 30 feet. An example of a roof of this form with details is given in Plates VI. and VII.

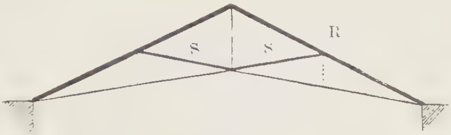


Fig. 521.

Common Trussed-rafter Roof.[1]—TRUSS WITH ONE STRUT.—Fig. 522 is an example of one of the earliest, and still one of the best and simplest forms of iron roof for small spans. In it each

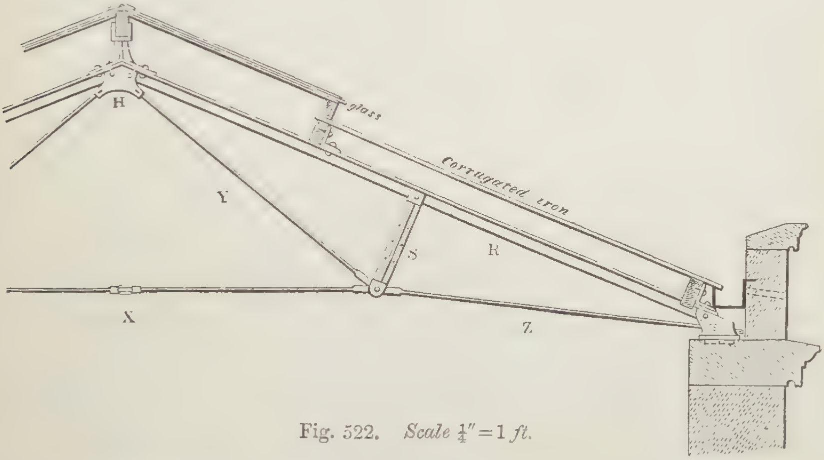


Fig. 522. *Scale* $\frac{1}{4}'' = 1$ *ft.*

rafter is trussed by means of a strut supporting it in the centre, the stress on the strut being taken up by tension rods which connect the head of the strut with the extremities of the rafter. The thrust upon the walls is counteracted by a horizontal tie rod joining the feet of the two struts, and which holds the trussed rafters together.

In this example the rafters are of T iron, the struts each of two T irons riveted together (see Fig. 545), with feet formed to receive the ends of the tension rods, as shown, and also those of the tie rod, which unites the two sides of the roof. The higher end of the upper tension rod (Y) is secured to the cast-iron head

[1] Sometimes called *Framed Roofs.*

H (see p. 282), and the foot of the lower tension rod (Z) passes through an iron shoe secured to the wall. Both tension rods can be slightly altered in length by means of cottered joints, and the tie rod by means of the union joint (X), so that they may be brought into a proper state of tension when the roof is fixed.

In the example given the upper purlin is arranged so as to support the lower side of the skylight, otherwise it would be better placed immediately over the head of the strut, so as to cause no cross strain upon the rafter.

In some varieties of this roof the intermediate tie is kept too high, which leaves a strain on the rafter similar to that experienced in a collar-beam roof (see p. 164).

"The merit of this truss is that the bracing is nearly all in tension.

"Mr. Bow has shown that, if the members are proportioned to the stress, it is more economical of material than any other form."[1]

This form of truss is adapted for spans of from 20 to 30 feet; it is, however, frequently used for much larger spans. Professor Unwin gives an instance in which it has been adopted for a span of 87 feet, but recommends at the same time that it should be restricted to spans of 60 feet.

As the span of the roof increases, the length of the rafters becomes such that they require support at more points than one.

The roof, Fig. 522, is old-fashioned in detail; a better example of a roof of this form is given in Plate V.

TRUSSED RAFTERS WITH TWO INCLINED STRUTS.—Fig. 523 gives an example adapted for spans of from 30 to 40 feet, in which the

Fig. 523.

rafter is supported at two intermediate points. An example of a roof of this form with details is given in Plate VIII. An example of a truss with two struts at right angles to each principal rafter is given in Plates IX. and X.

Queen-rod Roofs.[2]—These are modifications and extensions of

[1] Unwin's *Wrought-iron Bridges and Roofs.*

[2] Sometimes called *English roofs.*

the old timber roofs with Kings, Queens, and Princesses. (See Chap. XI.)

Fig. 524 shows an iron roof arranged in the form of the ordinary wooden queen-post[1] roof. The principal rafters and straining piece are of T

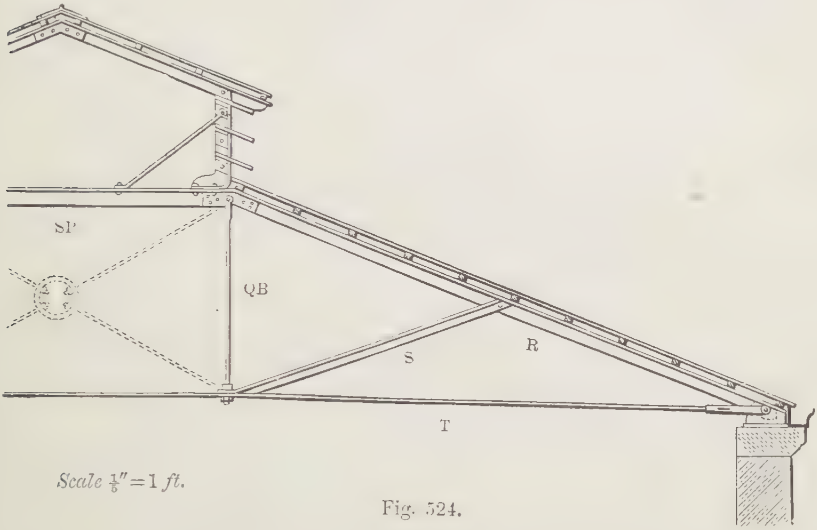


Fig. 524.

iron, the struts also of T iron, the queen rods and tie rod of circular rod iron.

The head of the rafters is secured to the straining piece by plates of iron covering the joint and riveted to both. The roof boarding is carried by horizontal common rafters, or, as they are usually called, "purlins," of angle iron filled in with wood. On the boarding may be laid slates, corrugated iron, sheet iron, or zinc.

The end of the tie rod is fastened to the rafter by a bolt, which, passing through both, secures them to a cast-iron shoe fixed upon the wall.

The tie rod may be slightly altered in length by the action of a cottered joint, which is described at p. 285.

The dotted lines show cross braces, which are often added in roofs of more than 30 feet span. In some cases the straining piece is supported in the centre by a curved T iron springing from the feet of the vertical bolts.

This roof is surmounted by a ventilator, the construction of which is obvious from the figure.

The example shown in Fig. 525 has rafters and struts of T iron, the tension and tie rods being all of round iron. The main tie rod is secured at the ends to wrought-iron plate shoes.

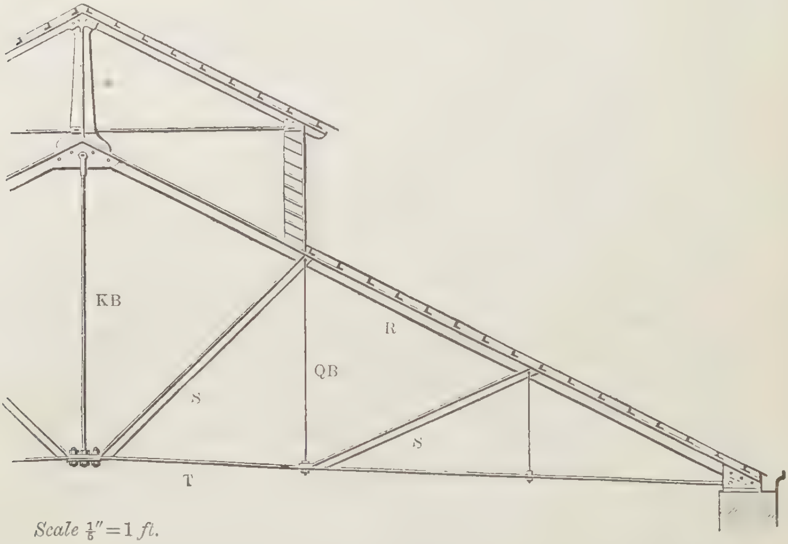
The roof covering of slates is carried by angle-iron purlins riveted to the back of the principal rafters.

[1] In iron roofs the term "*Queen-rod*" roof is generally applied to those having several suspending rods similar to the Princesses in wooden roofs.

The feet of the struts are secured to the tie rod by bolts with double nuts, figured and described at p. 284.

This roof is surmounted by a ventilator, consisting of cast-iron louvred standards supporting T-iron rafters, which carry angle-iron purlins similar to those of the main part of the roof.

The ventilator is strengthened by a tension rod passing across it and secured to the sides and centre standard by cottered joints.



Scale $\frac{1}{8}''=1$ *ft.*

Fig. 525.

A truss of this form is well adapted for carrying a roof covering resting on purlins placed just above the head of the struts, so that they cause no cross strain on the rafter.

An example of a saw-tooth roof trussed in the queen-rod form is given in Plate XI.

PARTS OF IRON TRUSSES.

Principal Rafters.—As these are in compression they were originally formed of cast iron, with the usual double-flanged section, frequently tapering in form, the lower flange being made wider in the centre of the length of the rafter than at the ends.

This material being, however, very heavy, and liable to snap suddenly, was soon generally abandoned.

Wrought-iron rafters for small roofs are most usually made of

a T section, with the table[1] uppermost, so as to form a base on which to fix the purlins.

For verandahs and roofs of small span covered with glass, T-iron rafters may be used with the table downwards, thus forming sash bars, the glass being fitted into the angles and resting upon the flanges.

Rafters of I section though they are sometimes used are not convenient for connecting to struts, etc. Rafters of double angle iron are more adapted for roofs of larger span than 40 feet, and will be described in Chapter XVIII.

Joints or Connections at Head of Principal Rafter. Heads or Crowns.

Heads.—*Wrought-iron Plate Joints.* The simplest way of securing the upper ends of T-iron rafters is by riveting a flat plate on each side of them, as shown in Figs. 519, 525, and in detail in Figs. 526, 527. This plate also serves to carry the upper end of the king bolt, or of other tension rods. The ends either pass between the plates as in Plates V., VIII., X., or are

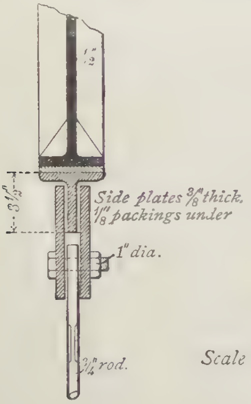


Fig. 526.

Scale 1" = 1 ft.

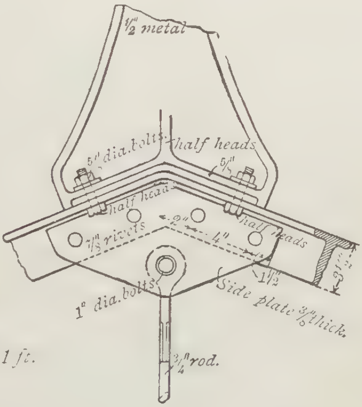


Fig. 527.

secured to them by being forked and passing on each side as in Fig. 519 and in Plate XI.

Cast-iron heads were formerly often used to receive the rafters, but being clumsy and easily broken, have become obsolete.

A very simple form of cast-iron head is shown in Fig. 528; the ends of the rafters pass into slots in the side of the head and

[1] In iron of T section the horizontal part of the T is called the *table*, and the vertical part the *web*.

are there secured by bolts; the upper part of the head is formed to receive the ridge board, and the body receives the king rod,

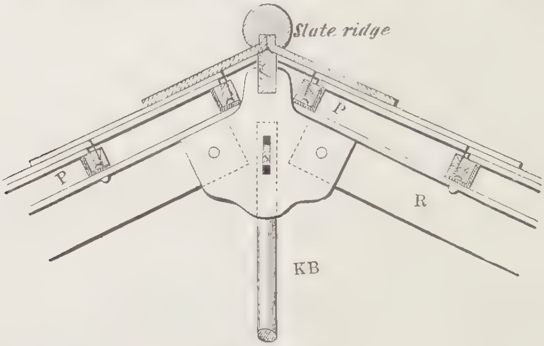
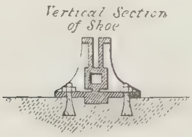


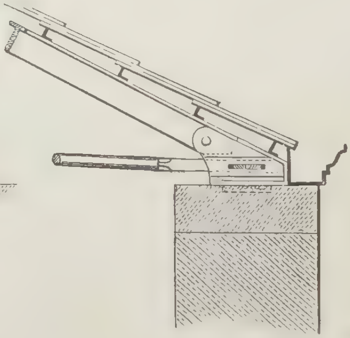
Fig. 528.

which is secured by a cottered joint arranged so that the rod may be slightly shortened in order to raise the tie rod and set up the truss when necessary.

The head shown in Fig. 522 is more complicated and bad in form; a comparatively slight blow on the projecting joints would fracture them.

Fig. 530.





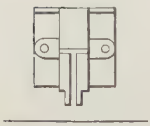


Fig. 529.

Fig. 531.

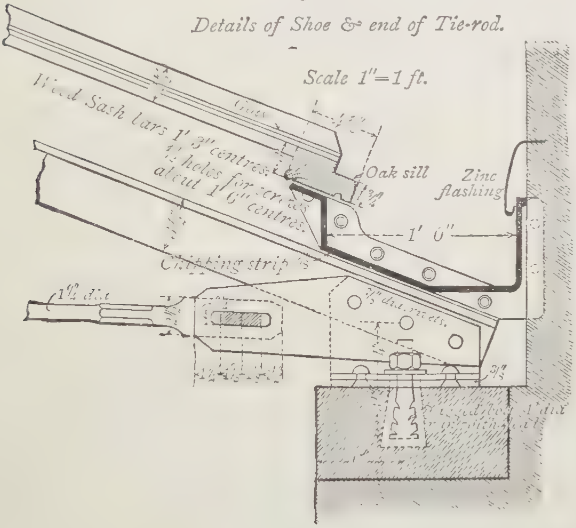
Joints or Connections at foot of Principal Rafter—Shoes.

Cast-iron Shoes.—The foot of the principal rafter is sometimes secured in a cast-iron shoe, in between the sides of which the vertical web of the rafter passes and is fastened by a bolt passing through it and the sides of the shoe.

Two or three examples of the commonest and simplest forms of these shoes are given in the figures 522, 524, and on a larger scale in Figs. 529, 530, 531, 538, 539; also in Plate VII., Figs. 563, 564, 572, Plate IX., Figs. 589, 590, 591.

Wrought-iron Plate Shoes.—Cast-iron shoes have to a great extent been superseded by simple joints constructed with flat plates to which the principal rafter is riveted, and the tie, if a rod, bolted, or if flat riveted to them. Examples of such joints are given in Figs. 552, 553, Plate V., and Figs. 573, 574, 575, Plate VIII., also Figs. 532, 533, 534, taken from an actual roof.

Fig. 532.



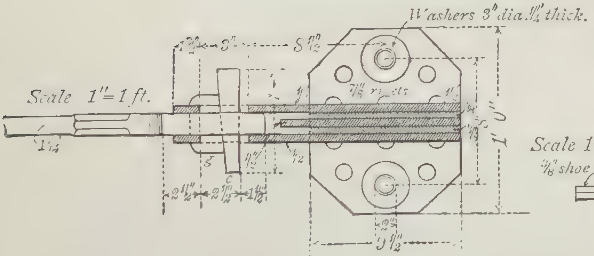


Fig. 533.

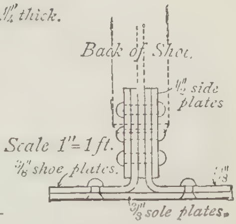


Fig. 534.

In large roofs, arrangements have to be made to allow free expansion and contraction of the iron, under changes of temperature, but these need not here be described; they will be referred to in Chapter XVIII.

Tie Rods are frequently of rod iron, circular in section. They may be flat bars on edge, which have an advantage, inasmuch as they are less liable to sag than a circular tie rod of the same strength. A flat bar, however, exposes a larger surface, and causes a heavy appearance in small roofs.

When flat bars are used, additional strength may easily be obtained by placing two or three bars side by side.

Where bolts pass through a tie rod, the latter is widened out so as to leave sufficient substance round the hole, in order that its tensional strength may not be reduced (see Fig. 544).

The tie rod may be simply bolted or riveted to the rafter (see Fig. 519), or to a shoe of some description (Figs. 522, 525).

When a king rod occurs, the centre of the tie rod is upheld by

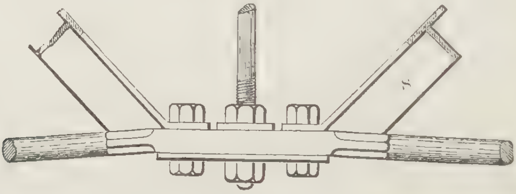


Fig. 535.

the king rod, which passes through it, and is secured by a nut on each side of it. The feet of the struts are attached to the tie rod in a similar way, as shown in Figs. 535, 543.

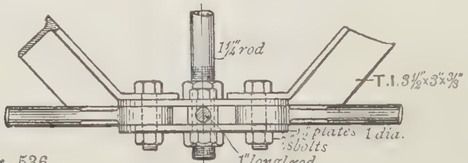


Fig. 536.

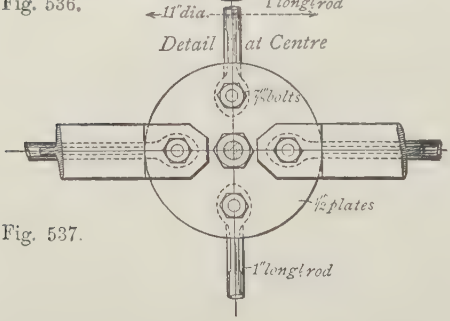


Fig. 537.

In larger roofs the tie rod is generally severed in the centre (Fig. 536), and in circular rods the ends thus formed are shaped into eyes, through

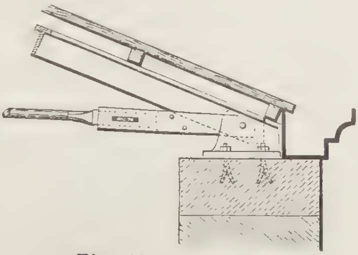
which pass the bolts securing the feet of the struts. The eyes are secured between flat plates, which may also take the end of any longitudinal tie rod, as in Figs. 536; 537, and Fig. 566, Plate VII. Flat tie rods are much more easily connected (see Plate V., Fig. 554, Plate VIII., Fig. 581, Plate X., Figs. 602, 603).

Cottered Joints.—These are used in connection with any member of a roof which it may be advisable to have the power of adjusting, so as to tighten up the truss after it has been put together and into position.

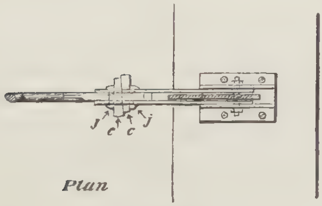
The construction of these joints is similar to that of the joint used by carpenters for connecting a king post with a tie beam, as explained at p. 171.

Figs. 538, 539 show a simple example of a cottered joint applied to the end of a tie rod. This being flattened out, passes

Fig. 538.



Elevation



Plan

Fig. 539.

between two plates which are bolted to the shoe, and lie on each side of the web of the rafter.

A rectangular slot is made through the plates and the end of the tie rod. In this slot are placed two iron wedges or "cotters" (*c c*), and the sides of the hole are protected and rendered smooth by means of wrought-iron *gibs* (*j j*), so that the wedges may slide easily when driven. As the wedges are driven inwards, they force the slot in the tie rod towards the shoe, so that it tends to coincide with the slot in the plates—thus the tie rod is shortened, and the

roof tightened up. A somewhat similar example is given in Fig. 606, Plate XI.

One cotter is frequently used instead of a pair (see Fig. 533), and has the same effect, for, as it is driven in, and the wider part enters the slot, it draws the two members in connection toward each other. Fig. 531 is an example of a cottered joint, the slot for which is formed in the shoe itself. Figs. 532, 533, 534 give details of a cottered joint connected with a wrought-iron shoe; and at H, Fig. 522, is an iron head of bad form (see p. 282), adapted for receiving two tension rods of a trussed-rafter roof, which are attached to it by cottered joints (see also Fig. 528). A taper of from $\frac{1}{4}''$ to $\frac{1}{2}''$ per foot of their length is generally given to the cotters.

Coupling boxes.—A *coupling box* or *union joint* (Figs. 540, 541) consists of a short hollow prism of iron with reverse screws tapped inside its ends, into which fit the screws on the ends of the portions of the rod to be connected; as the shackle is turned the ends are

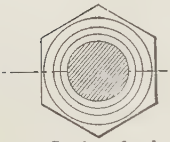


Fig. 541.

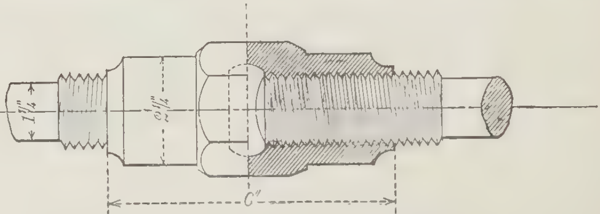


Fig. 540. *Scale 3″=1 ft.*

drawn inwards and the rod is shortened. The whole or part of the external surface is made polygonal so as to be capable of being turned by a spanner. The screws on the rod should have plus threads, that is threads standing above the surface of the rod, so as not to cut into or weaken it.

Suspending Rods.—These include *King bolts* or *King rods*, which hang from the apex of the roof, and all rods parallel to them which suspend the tie rod from the rafters.

In iron roofs all suspending rods except the *King bolt* or *King rod* are called *Queen bolts* or *Queen rods*.

These rods are generally formed with a fork at the upper end, so as to embrace the web of the principal rafter, to which they are secured by a bolt.

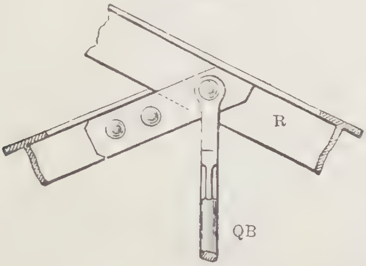
The lower ends of the rods pass through a hole in the tie rod,

and terminate in a screw carrying a nut, by screwing up which the tie rod may be raised and the truss set up.

Struts should, unless they are very short, be of wrought iron in preference to cast iron, as the latter are clumsy, apt to get broken in transit, and to snap suddenly in the work.

For small roofs the struts are generally made of angle or T iron, or sometimes of two T irons riveted together so as to form

Fig. 542.



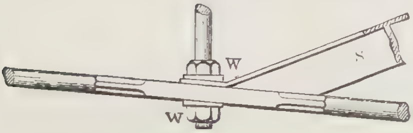


Fig. 543.

Plan of tie rod

Fig. 544.

a cross thus—  or of two channel irons similarly united.

Fig. 545.

Very efficient struts are formed by flat or angle irons kept apart by distance pieces, varying in length so as to form a tapering beam. Such a strut with one distance piece for a small roof is shown in Figs. 554, 555, Plate V., a longer one with three distance pieces in Fig. 595, Plate X.

Joints at head and foot of Struts.—The head of a T-iron or L-iron strut is usually secured to the rafter by flat strips or *ears* of iron placed on each side of the web of the strut, and riveted through that of the rafter (see Fig. 542, and Fig. 568, Plate VII.) The end of the web of the strut may be cut off obliquely to fit the under side of the rafter.

The foot of the strut is secured to the tie rod by a bolt passing

through the end of the table, which is turned up, and then secured with a double nut, as in Fig. 543. Washers, W W of a bevelled section, are required in order that the nut may communicate an even pressure to the flange of the strut.

Both the head and the foot of a strut may be very simply connected by the use of flat plates as in Figs. 577, 581, Plate VIII.

Cast-iron struts of a cross-shaped section are sometimes used, their upper ends being formed with jaws to seize the web of the principal rafter.

Purlins, properly so called, for carrying common rafters, are seldom used in small iron roofs.

Small purlins, or horizontal rafters, which themselves directly support the boarding or roof covering, are however in common use.

Iron Purlins.—These small purlins are generally of an L section—secured to the table of the Principal rafter by a *cleat* or bracket of angle iron (Fig. 546), or they are frequently filled in

Fig. 546.

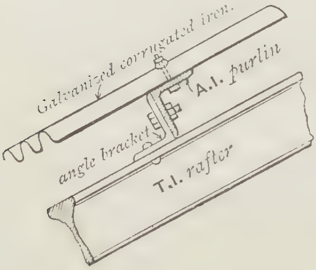
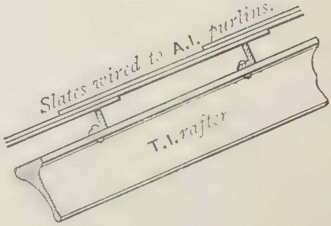


Fig. 548.



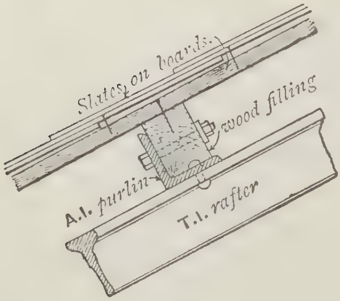


Fig. 547.

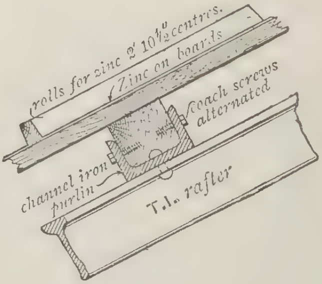


Fig. 549.

with wood, as shown in Fig. 547, for convenience in attaching the roof boarding or other covering.

Angle laths are small angle irons placed at a distance apart, equal to the gauge of the slates or the tiles they are to carry (Fig 548). These are directly attached to them by wire.

Iron purlins of channel section (the latter filled in with wood) are also sometimes used (Fig. 549), or two angle irons riveted on to the back of the principal rafter and filled in with wood.

WOODEN PURLINS are sometimes used. They may be notched on to the principal rafters, and secured to them either by an angle iron riveted to both, as in Fig. 522, or by being supported by a channel iron, as at P, Fig. 520.

The distance apart and arrangement of the purlins depend entirely upon the roof covering to be used.

Skylights and Lanterns.—Illustrations of *Skylights* are given in Fig. 522, Fig. 550, Plate V., Fig. 558, Plate VI., Figs. 568, 571, Plate VII.; of *Ventilators* in Figs. 524, 525, and Fig. 587, Plate IX.

Attachment to Columns and Girders.—This is dealt with in Chapter XVIII.

Coverings for Iron Roofs.—Several kinds of covering are used for iron roofs—such as slates, corrugated iron, sheet iron, cast-iron plates, tiles (occasionally), zinc, and glass.

The peculiarities of these different materials have been referred to in Chapter XII., while the subject of slating has been fully dealt with in Chapter XIII. (see p. 216).

Pitch of Iron Roofs.—The inclination of the slopes of iron roofs should, as in wooden roofs, depend upon the nature of the covering to be used.

With slates (the only covering at present under consideration) the pitch may vary, according to the size of the slates, and the climate, as stated at p. 216.

The steepest pitch there mentioned is, however, very seldom used for iron roofs, and in many cases where such roofs are erected—over railway stations, sheds, or other places where a slight leak is not of much importance—the slope is for economy made rather flat, 21° or 22° being a very common pitch for roofs covered with ordinary slating. Large slates are of course to be preferred for these flatter roofs, and "Duchesses" are very often used for the purpose.

Designing Iron Roofs.—In designing an iron roof it should be borne in mind that as many of the braces as possible should be in tension, and the struts should be as short as possible.

When there are only a few purlins widely spaced on the principal rafters, they should be immediately over the joints of the bracing of the roof, so as to prevent bending strains as much as possible.

In such a case the principal rafter is in compression throughout its length.

When, however, the weight is distributed throughout the length of the rafter by means of a number of small purlins, the principal rafter is subjected also to a transverse strain.

In either case the struts should not be so far apart as to necessitate the rafter being of too large a section for economy.

Elaborate forgings should be avoided, and all joints should be as simple as possible. The cast-iron connections between struts and ties so common in old roofs should be avoided.

"For a tensile strain it is safest to have bolts instead of rivets, and sometimes, if much depends on their strength, bolts with a nut at each end, so as to avoid the risk of a flaw in the forming of the bolt head."

"In the main tension rods of a roof screwed ends at all the points of connection are advantageous, welds are also so avoided and there is an opportunity for adjustment."

Care should be taken in designing a roof to use such forms, sections, and scantlings of iron as can be readily found in the market. Sections of peculiar dimensions, though perhaps a little lighter than the nearest sections kept by manufacturers, will not only cause delay but cost more.[1]

"In a roof which is rectangular in plan the distance apart of the Principals should be from $\frac{1}{8}$ to $\frac{1}{4}$ the span, and if these limits be overstepped there will be an unprofitable employment of material."[2]

It is sometimes economical to adopt the larger rather than the smaller interval, because, when the trusses are widely spaced, there is necessarily a large cross section given to the struts, but their length remains the same; they are, therefore, less liable to buckle under the thrust that comes upon them, and thus more resistance is obtained from an equal weight of metal.

A hipped roof is more expensive than one with gable ends, but the hipped end is a considerable support to the roof, and itself offers much less resistance to the wind than a gable.[3]

Trusses which do not contain vertical members are not so suitable for hipped roofs as those having such members.

Plates V. to XI.—Contract Drawings of Iron Roofs.

The illustrations of iron roofs and parts of iron roofs in the foregoing pages are intended to show the student clearly the construction of different types and forms of such structures generally. Such illustrations would not, however, do for the working

[1] For reference to British standard sections see Part III.

[2] Matheson, *Works in Iron*. [3] Maynard.

drawings required in practice, which must show the dimensions of the different parts of the actual roof required to be constructed.

These dimensions vary of course according to the span of the roof and other minor considerations—the larger the span, the greater will be the average of the scantlings or dimensions of the different members of the truss. To figure dimensions on the illustration of a type form might lead the student into the serious mistake of considering that there were standard dimensions applicable to all roofs.

In order, however, that the student may have a good idea of the kind of drawings required in practice, the Plates V. to XI. may with advantage be studied by him. They are reduced copies of the actual contract drawings that were used for the roofs illustrated, which have all been erected within the last few years. In some cases, however, the drawings of unimportant parts such as skylights, etc., have been left out for want of room.

Some of the plates may seem to be unnecessarily crowded with dimensions, etc., but it was thought better to retain them, so that the figures might be actual complete copies of the drawings of the different parts of the roofs.

PLATE V. contains the working drawings of a roof for a shed erected alongside a dock.

The truss is of the trussed-rafter form with a single strut. The *Principal Rafters* of T iron ; *Purlins*, wood ; *Tie Rods* of flat bar iron ; *Struts*, flat bars with distance pieces ; *Head* and *Shoes* of flat plates riveted together ; and the *Covering* of corrugated iron, with a small skylight.

PLATES VI. VII. are from the contract drawings for the roof of a store. The *Truss* is of the king-rod form with additional rods (as in Fig. 521) ; the *Rafters* and *Struts* are of T iron ; the *Suspending Rods* and *Tie Rod* of round iron ; *Purlins*, timber ; *Covering*, half of slates and half of glass. It will be noticed that this roof springs on one side from a rolled iron beam resting on columns, as in Figs. 558 and 572, on the other side from a wall, as shown in Figs. 559, 563, 564. There is provision made at a lower level for rails to carry a traveller for moving goods.

PLATE VIII. is a reduced copy of one of the type plans, signed by Sir Alexander Rendel and Sir Guildford Molesworth, for a roof on the Indian State Railways. The *Truss* is of the trussed-rafter form with two inclined struts ; the *Rafters* of T iron ; *Purlins* of angle irons fixed by angle-iron brackets ; *Struts* of T iron ; *Heads, Shoes, and other joints* of flat plates ; *Tension and Tie Rods* of flat bar iron ; *Covering* of corrugated iron, with a ridge cap of the same. The *Rivets* are of $\frac{3}{4}''$ diameter throughout.

PLATES IX. X. are, by the kind permission of Sir John Coode, K.C.M.G., reduced from the working drawings of a roof for an engine house erected by him at the Cape. The *Truss* is of the trussed-rafter type with two struts, normal to the *Rafters*, which are of T iron ; *Struts*, flat bars with distance pieces ; *Purlins*, angle irons filled in with wood ; *Head* of flat plates ;

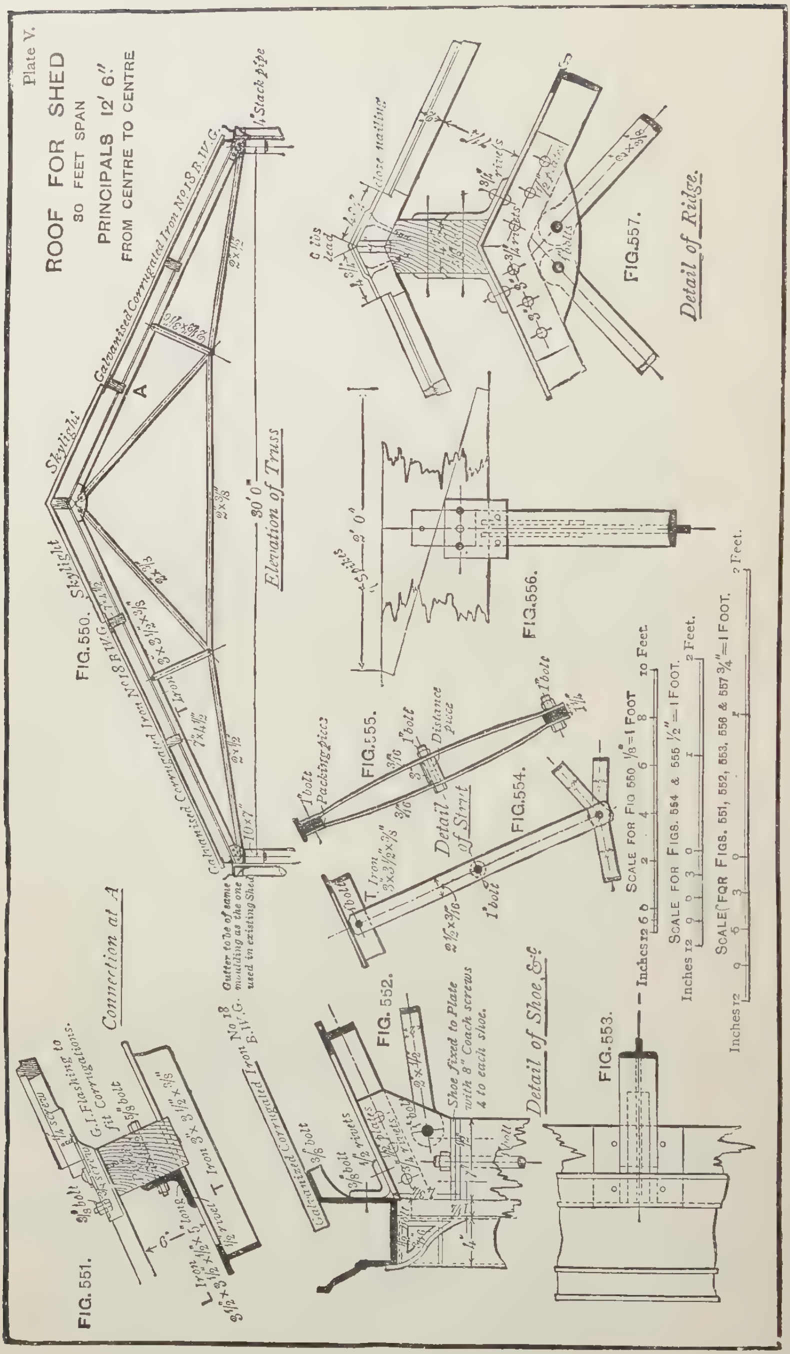
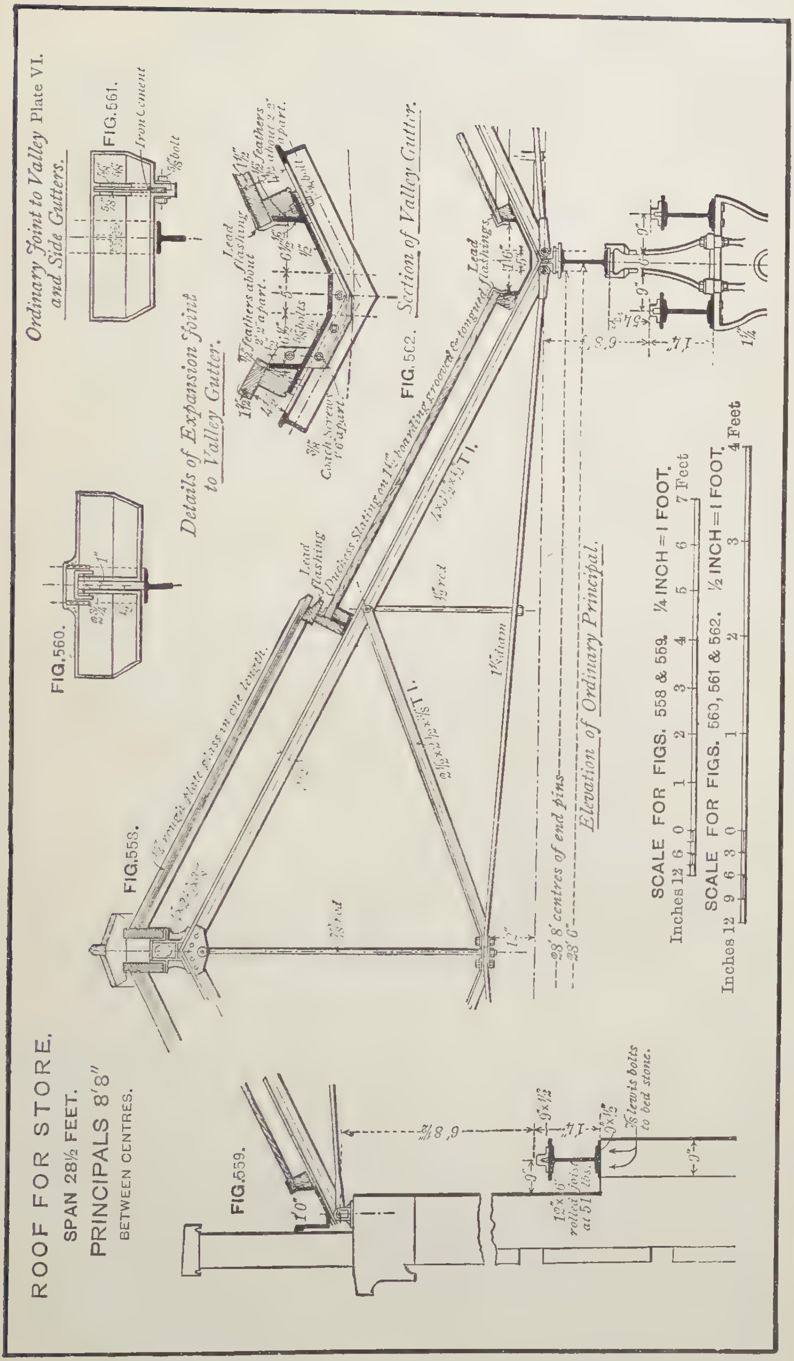


Plate V.
ROOF FOR SHED
30 FEET SPAN
PRINCIPALS 12' 6"
FROM CENTRE TO CENTRE
FIG. 550.
Skylight
Galvanised Corrugated Iron No 18 B.W.G.
Elevation of Truss
30' 0"
Stack pipe
FIG. 551.
Connection at A
G.I. Flashing to fit Corrugations.
FIG. 552.
Galvanised Corrugated Iron No 18 B.W.G.
Gutter to be of same moulding as the one used in existing Shed
Shoe fixed to Plate with 8" Coach screws 4 to each shoe.
Detail of Shoe, &c.
FIG. 553.
FIG. 554.
FIG. 555.
Packing piece
Distance piece
Detail of Strut
FIG. 556.
FIG. 557.
close nailing
Detail of Ridge.
Scale for Fig 550 1/8" = 1 Foot
Scale for Figs. 554 & 555 1/2" = 1 Foot.
Scale for Figs. 551, 552, 553, 556 & 557 3/4" = 1 Foot.


ROOF FOR STORE.
SPAN 28½ FEET.
PRINCIPALS 8'8"
BETWEEN CENTRES.
Ordinary Joint to Valley Plate VI. and Side Gutters.
FIG. 561.
Iron Cement
FIG. 560.
Details of Expansion Joint to Valley Gutter.
Coach Screws 1'6" apart.
FIG. 562. Section of Valley Gutter.
FIG. 558.
¼" rough plate glass in one length.
Lead flashing
Duchess Slating on 1¼" boarding grooved & tongued
Lead flashings
28' 8" centres of end pins
28' 6"
Elevation of Ordinary Principal.
FIG. 559.
12"x6" rolled joist at 51 lbs.
⅞ lewis bolts to bed stone.
SCALE FOR FIGS. 558 & 559. ¼ INCH = 1 FOOT.
Inches 12 6 0 1 2 3 4 5 6 7 Feet
SCALE FOR FIGS. 560, 561 & 562. ½ INCH = 1 FOOT.
Inches 12 9 6 3 0 1 2 3 4 Feet

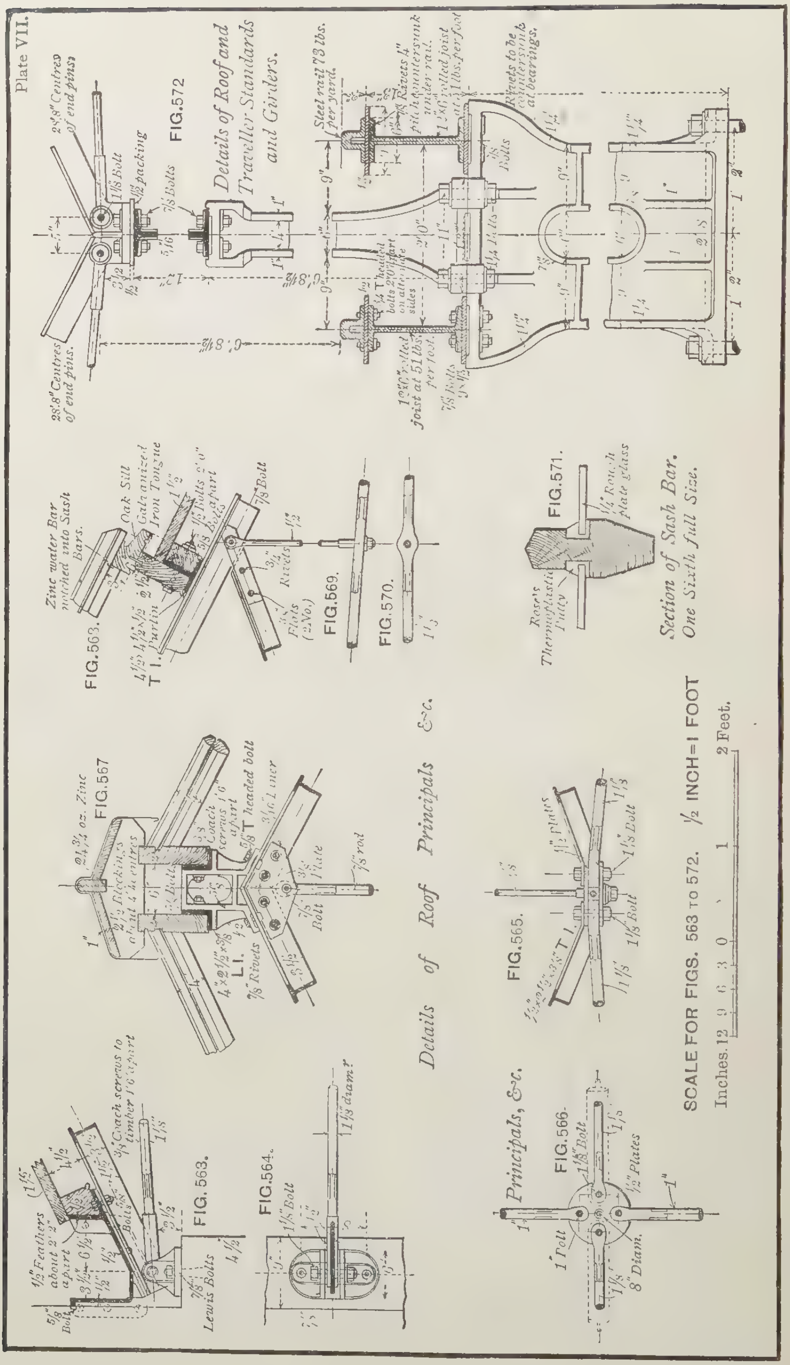


Plate VII.
Details of Roof Principals &c.
Details of Roof and Traveller Standards and Girders.
FIG. 563.
FIG. 564.
FIG. 565.
FIG. 566.
FIG. 567
FIG. 568.
FIG. 569.
FIG. 570.
FIG. 571.
FIG. 572
Section of Sash Bar. One Sixth full Size.
SCALE FOR FIGS. 563 TO 572. ½ INCH=1 FOOT
Inches 12 9 6 3 0 1 2 Feet.

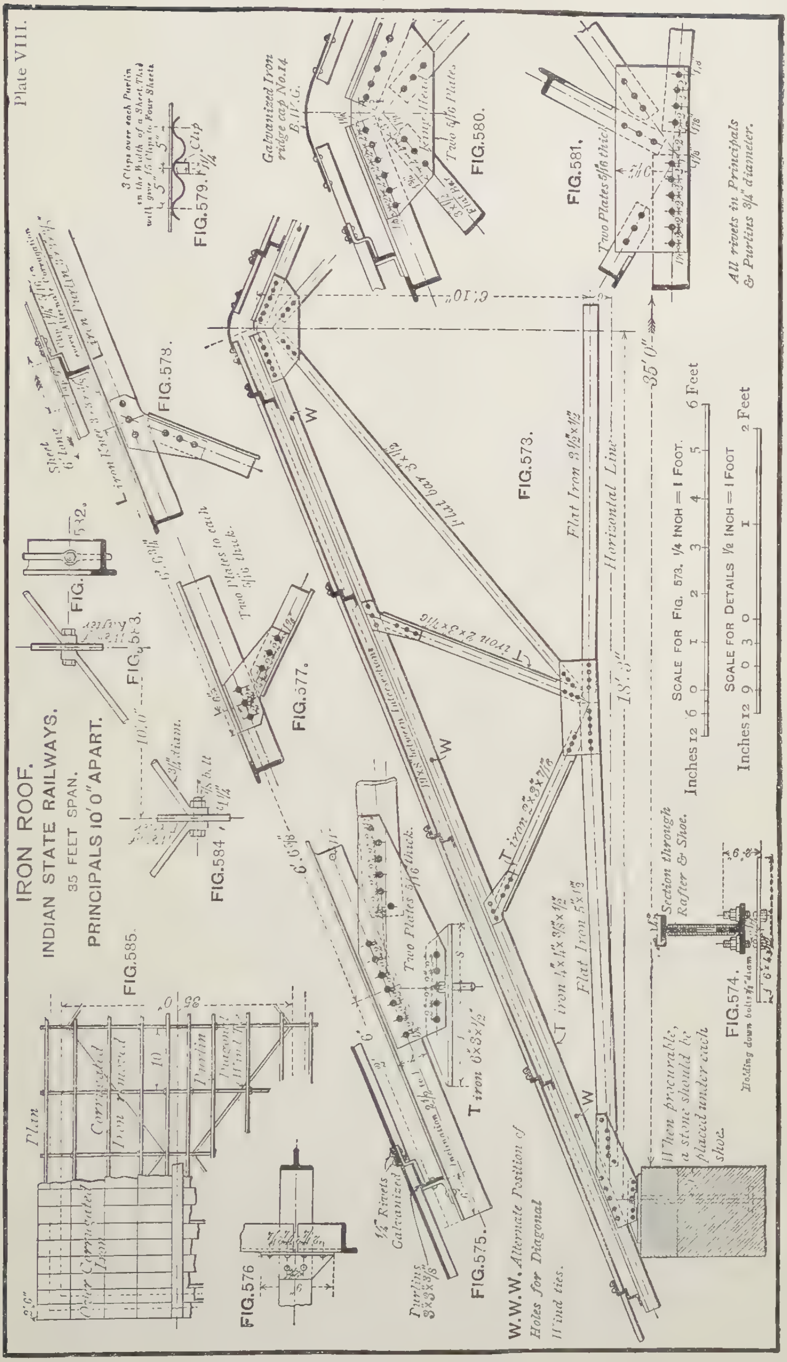


Plate VIII.
IRON ROOF.
INDIAN STATE RAILWAYS.
35 FEET SPAN.
PRINCIPALS 10'0" APART.
FIG. 585.
FIG. 584
FIG. 583.
FIG. 582.
FIG. 578.
FIG. 579.
FIG. 577.
FIG. 576
FIG. 575.
FIG. 574.
FIG. 573.
FIG. 580.
FIG. 581.
Galvanized Iron ridge cap No. 14 B.W.G.
Two Plates to each 5/16 thick.
Two Plates 5/16 thick.
Two 5/16 Plates
Flat bar 3 x 1/2
T iron 2 x 3 x 7/16
T iron 2 1/2 x 3 x 7/16
T iron 4" x 4" x 3/8 x 1/2
Flat Iron 5" x 1/2
Flat Iron 3 1/2" x 1/2
T iron 6" x 3" x 1/2"
Horizontal Line
35' 0"
18' 3"
6' 10"
6' 6 3/8"
Section through Rafter & Shoe.
When procurable, a stone should be placed under each shoe.
1/4" Rivets Galvanized
Purlins 3 x 3 x 3/8
Plan
Corrugated Iron
Purlin
W.W.W. Alternate Position of Holes for Diagonal Wind ties.
All rivets in Principals & Purlins 3/4" diameter.
SCALE FOR FIG. 573. 1/4 INCH = 1 FOOT.
Inches 12 6 0 1 2 3 4 5 6 Feet
SCALE FOR DETAILS 1/2 INCH = 1 FOOT
Inches 12 9 0 3 0 1 2 Feet

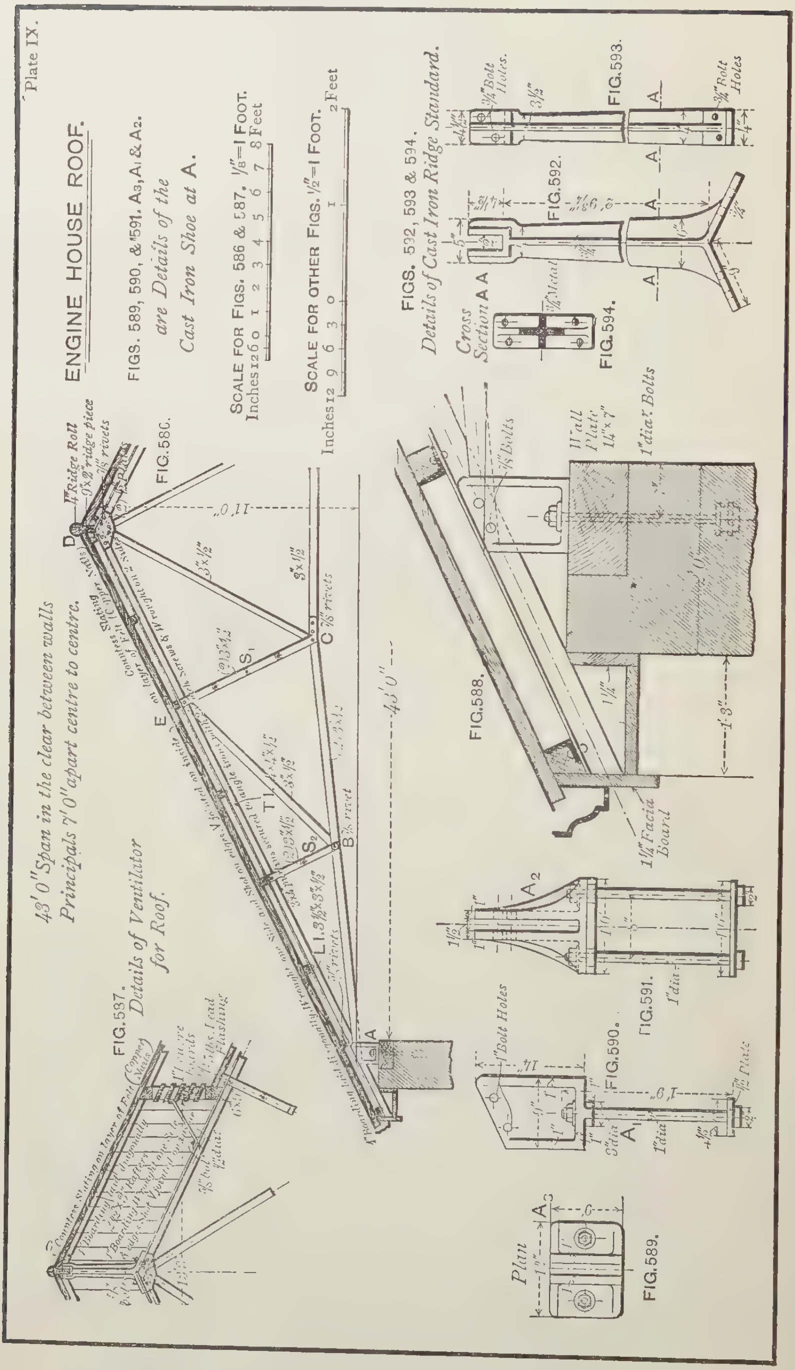


Plate IX.
ENGINE HOUSE ROOF.
43' 0" Span in the clear between walls
Principals 7' 0" apart centre to centre.
FIGS. 589, 590, & 591. A3, A1 & A2.
are Details of the
Cast Iron Shoe at A.
SCALE FOR FIGS. 586 & 587. 1/8"=1 FOOT.
SCALE FOR OTHER FIGS. 1/2"=1 FOOT.
FIG. 586.
FIG. 587.
Details of Ventilator
for Roof.
FIG. 588.
FIGS. 592, 593 & 594.
Details of Cast Iron Ridge Standard.
Cross Section A A
FIG. 594.
FIG. 592.
FIG. 593.
FIG. 589.
FIG. 590.
FIG. 591.
Plan
Wall Plate 14"x7"
1" dia. Bolts
1 1/4" Facia Board
3/4" Bolt Holes
7/8" rivets
43' 0"
11' 0"
1' 8"

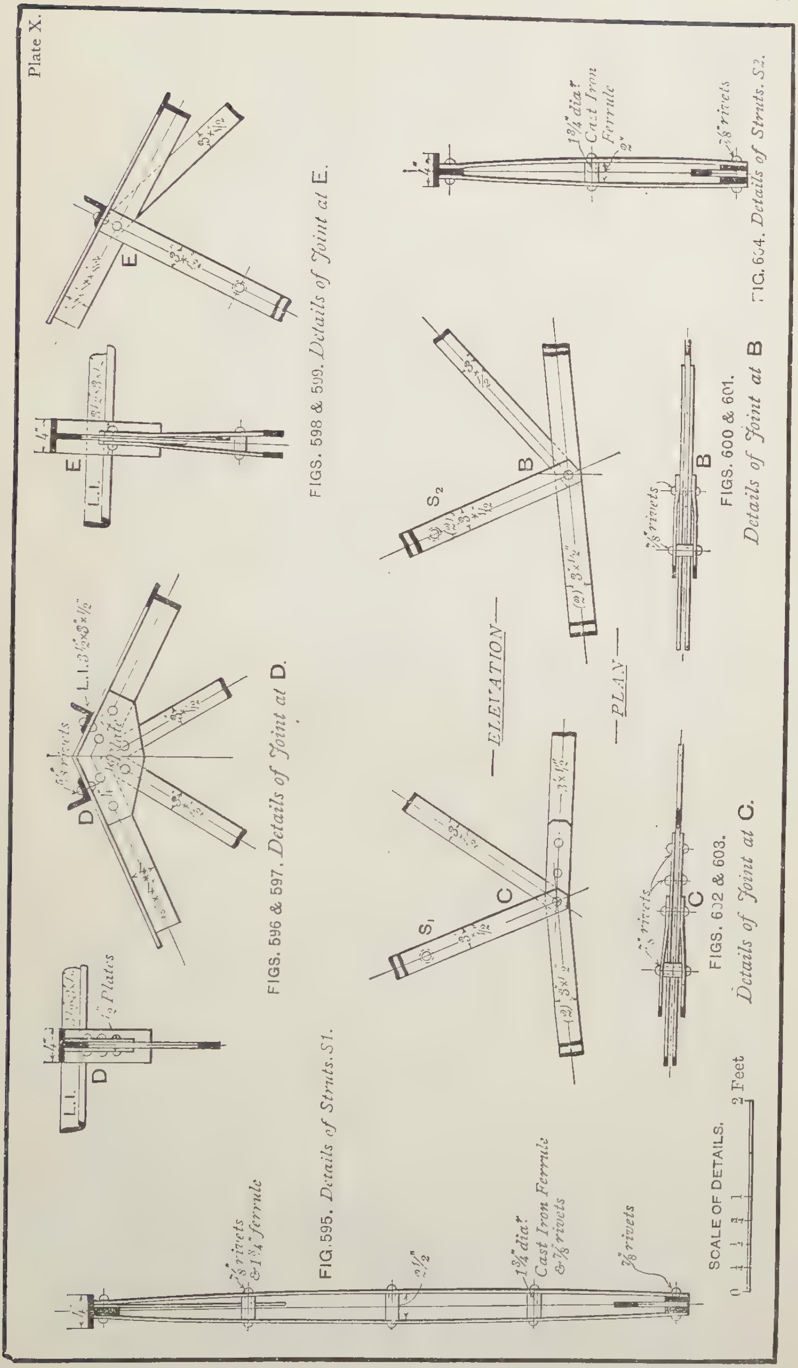


FIG. 595. Details of Struts. S1.

FIGS. 596 & 597. Details of Joint at D.

FIGS. 598 & 599. Details of Joint at E.

FIGS. 600 & 601. Details of Joint at B.

FIGS. 602 & 603. Details of Joint at C.

FIG. 604. Details of Struts. S2.

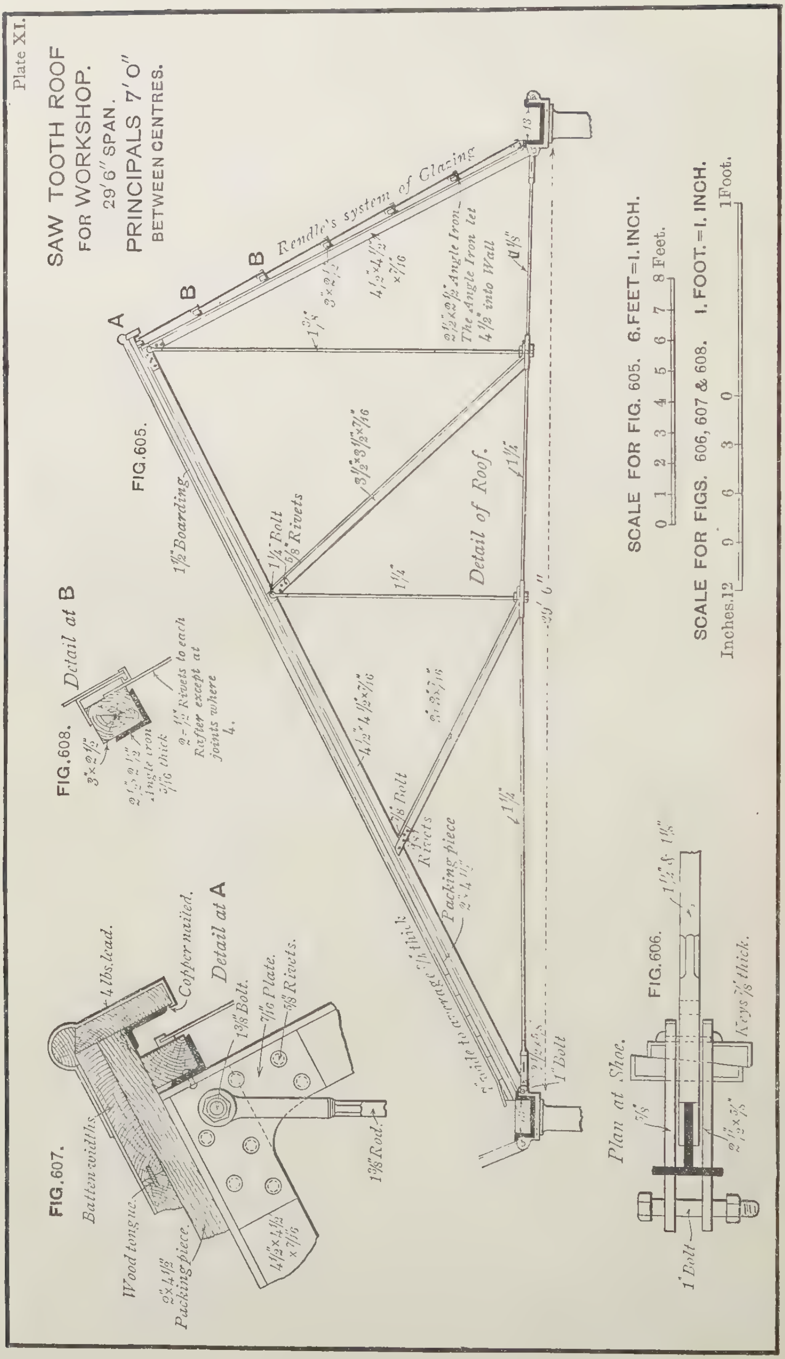


Plate XI.
SAW TOOTH ROOF
FOR WORKSHOP.
29′ 6″ SPAN.
PRINCIPALS 7′ 0″
BETWEEN CENTRES.
FIG. 605.
Detail of Roof.
1½″ Boarding
Rendle's system of Glazing
1¼″ Bolt
⅝″ Rivets
⅞″ Bolt
Rivets
Packing piece 2″×4½″
4½″×4½″×7/16″
3½″×3½″×7/16″
4½″×4½″ ×7/16″
2½″×2½″ Angle Iron. The Angle Iron let 4½″ into Wall
1 Bolt
29′ 6″
FIG. 606.
Plan at Shoe.
1″ Bolt
2½″×⅝″
Keys ⅞″ thick.
1½″ & 1⅛″
FIG. 607.
Detail at A
Batten widths.
4 lbs. lead.
Wood tongue.
2″×4½″ Packing piece.
Copper nailed.
1⅜″ Bolt.
7/16″ Plate.
⅝″ Rivets.
4½″×4½″ ×7/16″
1⅜″ Rod.
FIG. 608.
Detail at B
3″×2½″
2½″×2½″ Angle iron 5/16″ thick
2 - ½″ Rivets to each Rafter except at joints where 4.
SCALE FOR FIG. 605. 6. FEET = 1. INCH.
0 1 2 3 4 5 6 7 8 Feet.
SCALE FOR FIGS. 606, 607 & 608. 1. FOOT. = 1. INCH.
Inches. 12 9 6 3 0 1 Foot.

Shoe of cast iron; *Tension Rods*, flat bars; and *Tie Rod*, double flat bars. A *Ventilator* extends along part of the roof, details of which are given in Figs. 587 and 592 to 594.

PLATE XI. is a section of a workshop roof, so arranged as to admit light from one side only, which should be the north, and called from its shape, a *Saw-tooth roof.* The *Truss* is of the queen-rod type; *Rafters and Struts*, T iron; *Tie and Tension Rods*, round iron; *Head*, joint with plates; *Shoe*, lug cast on top of column; *Covering*, zinc, on boarding, except on north side when one of the many systems of glazing without putty (Rendles, see Part II.) is used.

Cost.—This subject is outside the scope of these Notes, but will be found well treated in Adam's *Designing Wrought-and Cast-iron Structures, Part V.*

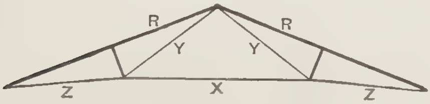


Fig. 609.

PROPORTIONS OF TRUSSED-RAFTER ROOFS (see Fig. 609) from 20 to 45 feet span.[1] Rise $= \frac{1}{5}$ span. Camber of tie rod $= \frac{1}{30}$ span. Principals 6′ 8″ apart.

Span in feet	Rafter T iron. Dimensions in inches. R	Diameter of Tension Rods in Inches. Between heads of Struts. X	Between head of Strut and foot of Rafter. Z	Between head of Strut and apex of Roof. Y
20	$2\frac{1}{2}$ by 2 by $\frac{3}{8}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{5}{8}$
25	$2\frac{3}{4}$,, 2 ,, $\frac{3}{8}$	$\frac{3}{4}$	1	$\frac{3}{4}$
30	$2\frac{3}{4}$,, $2\frac{1}{2}$,, $\frac{1}{2}$	$2\frac{1}{4}$ by $\frac{1}{4}$	$2\frac{1}{4}$ by $\frac{3}{8}$	$2\frac{1}{4}$ by $\frac{1}{4}$
35	3 ,, $2\frac{3}{4}$,, $\frac{1}{2}$	$2\frac{1}{2}$,, $\frac{5}{16}$	$2\frac{1}{2}$,, $\frac{1}{2}$	$2\frac{1}{2}$,, $\frac{5}{16}$
40	$3\frac{1}{4}$,, 3 ,, $\frac{1}{2}$	$2\frac{1}{2}$,, $\frac{3}{8}$	$2\frac{1}{2}$,, $\frac{5}{8}$	$2\frac{1}{2}$,, $\frac{3}{8}$
45	4 ,, $3\frac{1}{2}$,, $\frac{1}{2}$	3 ,, $\frac{3}{8}$	3 ,, $\frac{1}{2}$	3 ,, $\frac{3}{8}$

[1] From Molesworth's *Pocketbook of Engineering Formulæ.*

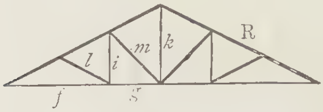


Fig. 610.

PROPORTIONS OF WROUGHT-IRON QUEEN-BOLT ROOFS (see Fig. 610) from 20 to 40 feet span usually adopted in practice.[1] Rise $= \frac{1}{4}$ span. Camber of tie rod $= \frac{1}{30}$ span. Distance apart of trusses 8 feet.

Span.	Tie Rod, Diameter.		Bolts, Diameter.		Struts, Sectional Area.		T Rafters.
	f	*g*	*i*	*k*	*l*	*m*	R
Feet.	"	"	"	"	"	"	Inches.
20	$\frac{15}{16}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	0·8	0·9	$3\frac{1}{4} \times 2\frac{1}{2} \times \frac{7}{16}$
22	$\frac{15}{16}$	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	0·9	1·0	$3\frac{1}{2} \times 2\frac{1}{2} \times \frac{7}{16}$
24	1	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{11}{16}$	1·0	1·1	$3\frac{1}{2} \times 2\frac{3}{4} \times \frac{7}{16}$
26	$1\frac{1}{16}$	$\frac{15}{16}$	$\frac{1}{2}$	$\frac{11}{16}$	1·1	1·2	$3\frac{3}{4} \times 2\frac{3}{4} \times \frac{7}{16}$
28	$1\frac{1}{16}$	1	$\frac{1}{2}$	$\frac{11}{16}$	1·2	1·3	$4 \times 2\frac{3}{4} \times \frac{7}{16}$
30	$1\frac{1}{8}$	1	$\frac{1}{2}$	$\frac{3}{4}$	1·2	1·4	$4 \times 3 \times \frac{1}{2}$
32	$1\frac{3}{16}$	$1\frac{1}{16}$	$\frac{1}{2}$	$\frac{3}{4}$	1·3	1·5	$4\frac{1}{4} \times 3 \times \frac{1}{2}$
34	$1\frac{3}{16}$	$1\frac{1}{16}$	$\frac{1}{2}$	$\frac{13}{16}$	1·3	1·5	$4\frac{1}{2} \times 3 \times \frac{1}{2}$
36	$1\frac{1}{4}$	$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{13}{16}$	1·4	1·6	$4\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$
38	$1\frac{1}{4}$	$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{13}{16}$	1·5	1·7	$4\frac{3}{4} \times 3\frac{1}{2} \times \frac{1}{2}$
40	$1\frac{5}{16}$	$1\frac{3}{16}$	$\frac{1}{2}$	$\frac{13}{16}$	1·5	1·7	$4\frac{3}{4} \times 3\frac{1}{2} \times \frac{5}{8}$

[1] From Hurst's *Architectural Surveyor's Handbook.*

Chapter XVIII.

STEEL OR IRON ROOFS[1]—(*Continued*).

THIS Chapter includes roofs of from 40 to 60 feet span.

Such roofs come under the first head of the classification given in Chapter XVII., as they can easily be formed with straight rafters, and it will therefore be unnecessary to notice roofs with arched rafters or mixed roofs in these Notes.

Plate IV. shows various forms of trusses for iron roofs of spans up to 60 feet. As it has already been described on p. 275, nothing need be said about it here. It will be noticed that the trusses are so arranged that the principal rafters are supported at intervals not greater than 8 feet.

Trussed Rafter Roofs.—On p. 277 illustrations and descriptions were given of a roof in which each principal rafter was trussed by means of a strut supporting it in the centre (Figs. 502, 503), the strut itself being sustained by tension rods connecting it with the ends of the rafter.

Such an arrangement is best adapted for roofs up to 30 or 40 feet span; but when, as in larger roofs, the rafters become very long, they require support at more than one central point.

Truss with two Struts.—Figs. 504, 505, 506, Plate IV., show various forms in which a truss with two struts to support the principal rafter may be constructed. Details of such trusses are given in Plates VIII. IX. Chapter XVII., also in Plates XII. XIV. of this Chapter.

Truss with three Struts.—In roofs of more than 40 feet span the rafters become so long as to require support at three intermediate points; the same principle of trussing may be continued as shown in Fig. 507 and in Plate XVI.

Fig. 611 on page 302 is also an example of a trussed rafter roof with 3 struts. In this example the rafters are of T iron, the struts of double T iron riveted back to back. The tie rod and upper tension rod are of round iron, and the lower tension rod is of double flat bar iron.

The covering is of slates laid on boarding supported by angle-iron purlins filled in with wood.

[1] The greater uniformity of quality of Mild Steel, combined with its superior strength and elasticity, have caused it to practically supersede wrought iron both in roofing and girder work. A description of the qualities and tests of steel of a class suitable for work of this kind, will be found in Part III. Chapter IV. See also footnote to p. 272.

The roof is surmounted by a skylight, supported by a cast-iron standard, and provided with wooden or iron louvres.

With regard to trussed rafter roofs Mr. Matheson says,[1] the "forms just described are marked by an absence of vertical members, and for this reason the

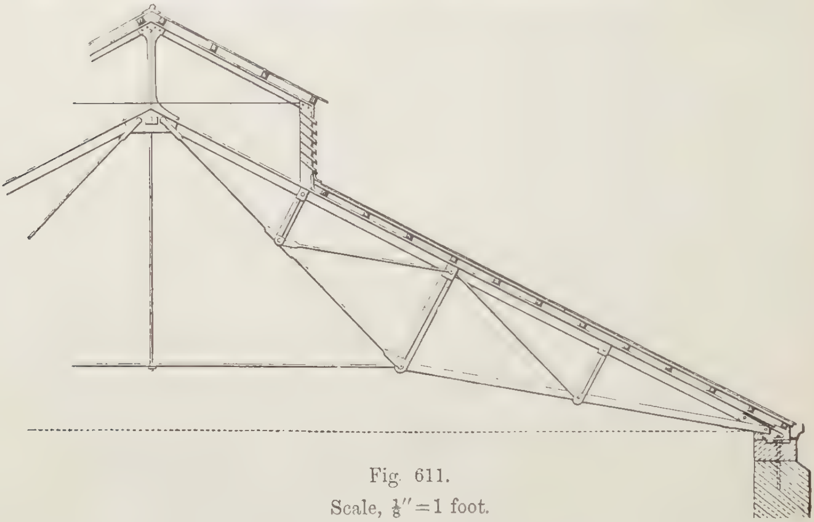


Fig. 611.
Scale, $\frac{1}{8}''=1$ foot.

system is not a convenient one for hipped roofs, and for those roofs also where a longitudinal bracing between the principals is required in a vertical plane."

Queen-Rod Roofs.—A form of queen-rod roof suitable for spans of from 30 to 40 feet was given in Chap. XVII.

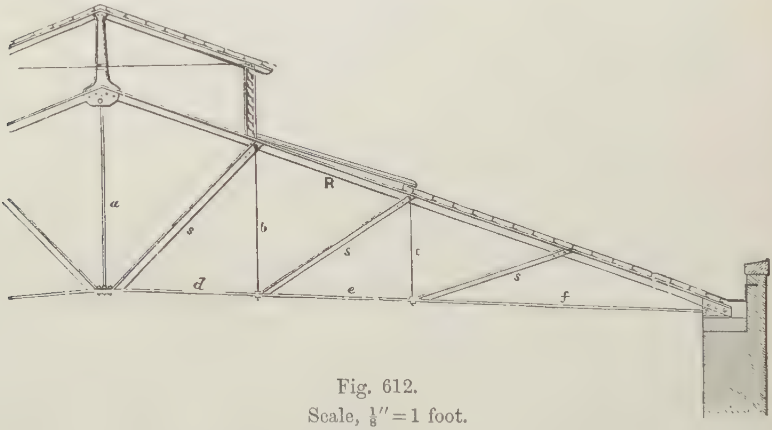


Fig. 612.
Scale, $\frac{1}{8}''=1$ foot.

Fig. 612 shows an extension of the same principle adapted for use in roofs of from 40 to 60 feet span.

[1] *Works in Iron.*

In this example the rafters and struts are of T iron, the tension and suspending rods of round iron. The covering is of Duchess slates laid on angle iron laths. The ridge lantern is of similar construction to that last described, covered with slates on angle iron laths, and supported by cast-iron standards.

A side skylight is shown just below the lantern consisting of T iron sash bars, filled in with glass.

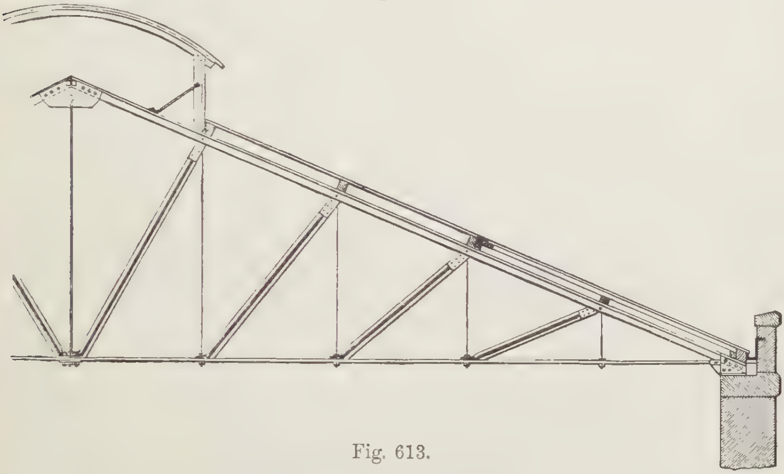


Fig. 613.

Scale, $\frac{1}{10}'' = 1$ foot.

Fig. 613 shows an extension of the form of truss just described, adapted for roofs of from 50 to 75 feet span.

In this case the struts may be of double T iron, riveted back to back, or of double bar or double angle, or double T irons kept asunder by cast-iron distance pieces. The rafters of double angle iron and the purlins of wood sustaining boarding, on which may be laid slates, zinc, or other roof covering.

The lantern is of simple construction, consisting merely of corrugated iron resting upon curved ribs of T iron, and supported by T iron side standards.

The lower portion of the roof slope is covered by an ordinary wooden sash skylight resting upon the purlins.

Modification of Queen-Rod Roof.—Fig. 614 shows a modification of the queen-rod roof often used in practice.[1]

In this form of roof the struts are at right angles to the rafter, and are therefore of minimum length.

In the example given the struts are of double bar iron of the

[1] This example was taken from the roof of a drill shed.

construction described at page 305, the rafters of T iron, the

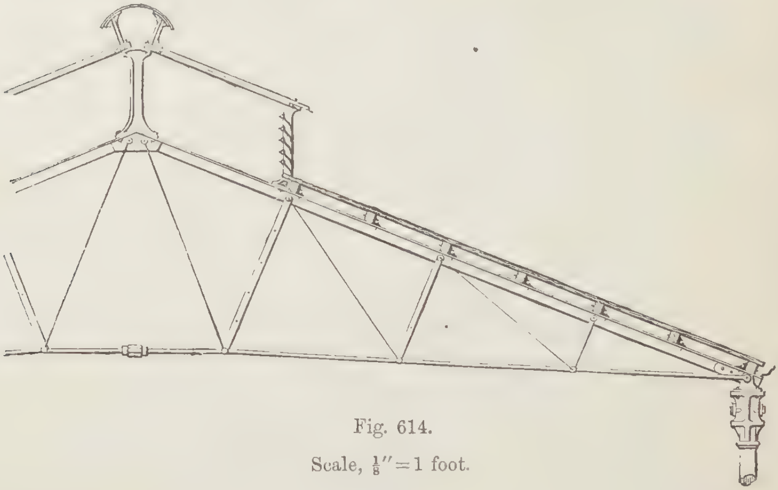


Fig. 614.

Scale, $\frac{1}{8}''=1$ foot.

tension and tie rods of round iron, the purlins of wood connected to the rafters by angle iron.

The skylight is shown on a larger scale in Fig. 636, page 313, and is there described.

The tie rod is attached to chairs formed upon the heads of the columns supporting the roof (see Figs. 633, 634), and is provided with a union joint in the centre by which it may be tightened.

PARTS OF IRON ROOF TRUSSES.

The methods of constructing the different parts for iron roofs of small span have already been described in Chap. XVII. This section will be confined to the consideration of the forms to be given to members of somewhat larger roof trusses.

Principal Rafters.—It has already been mentioned on p. 275 that the principal rafters of an iron roof of small span are generally of T shaped section.

Bars of similar sections, but of larger dimensions, are also used for larger roofs; but in these many other forms are also adopted, a few of which may now be mentioned.

Rafters of I section have been sometimes used for spans of over 60 feet, but are not convenient for the attachment of the struts.

When T iron is used for larger roofs the upper flange may be strengthened by adding plates to it, as in Fig. 615.


Fig. 615.

"Bulb iron with a thin web and a bulb somewhat larger than the top table, gives a greater resistance with the same weight of metal than T iron, but its cost is considerably greater, and it is not quite so easy to connect with the other part of the truss." [1]

The increased strength required in long rafters has sometimes been given without increasing the depth of the iron used by placing two bars side by side, parallel to one another, and kept an inch or two apart by means of cast-iron distance pieces.

Double channel iron may be similarly used, thus—

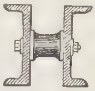


Fig. 616.

or double angle iron, thus—


Fig. 617.

the latter are the more convenient for connecting with the heads of struts, etc.

Hip Rafters may be strengthened by the introduction of additional flat plates, thus—


Fig. 618.

without much increasing the bulk of the rafter.

Purlins for roofs of from 40 to 60 feet span may be of timber (Fig. 614); of angle iron (Fig. 612); T iron, or channel iron, as already described and illustrated in Chap. XVII. The angle and channel iron may be filled in with wood (Fig. 620) in order that the roof covering may be more easily attached.

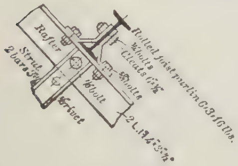


Fig. 619.

In larger roofs, where the principals are widely spaced, the purlins may be of I iron (Fig. 619), or latticed (see Plate XVI. Fig. 672).

Struts.—The forms of wrought-iron struts described on p. 287, viz. those made of angle or T iron, are frequently used for roofs of spans up to 40 or 60 feet.

A better form, however, is the strut of cruciform section, consisting of two T irons riveted back to back, as in Fig. 611.

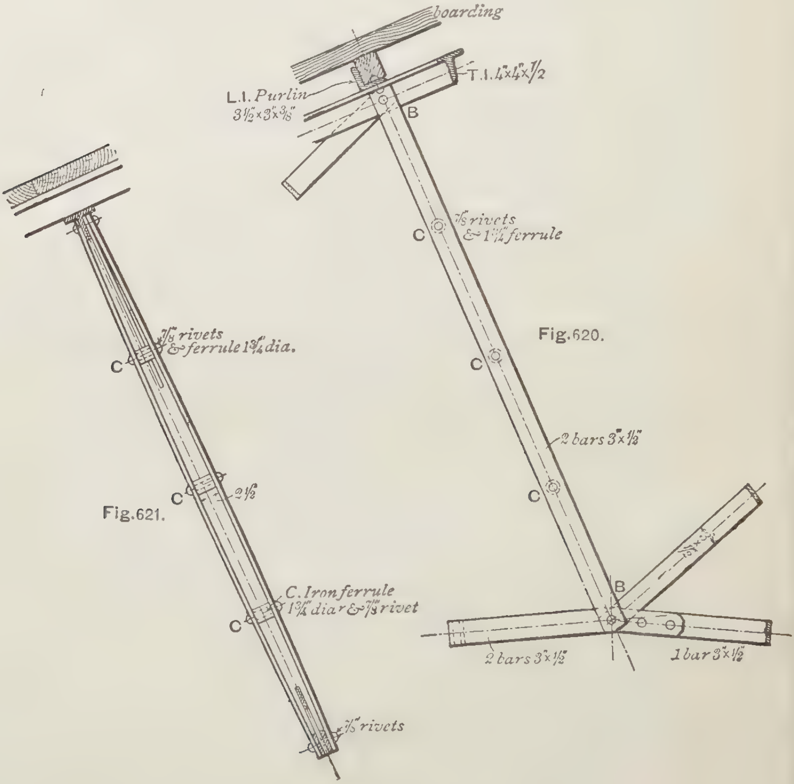
Strong and light struts formed out of wrought-iron gas tubing fitted with cast-iron sockets at the ends are sometimes used.

Another very good form was noticed on p. 291. It consists of

[1] Wray's *Theory of Construction.*

two flat bars, Figs. 620, 621, kept apart by cast-iron distance pieces, *c c c*, varying in length so as to form a strut tapering from the centre toward the ends.

Such a strut is shown in Fig. 614, also in Plates XIV. XVI., and a similar one on an enlarged scale in Figs. 620, 621. L or T irons are sometimes substituted for the flat bars.



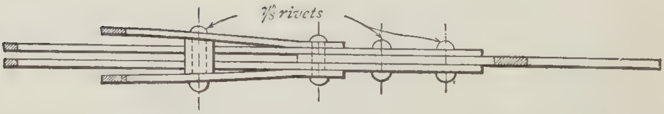


Fig. 622. (ENLARGED SCALE) PLAN AT B.

Scale for Figs. 620, 621, ½ inch = 1 foot.
" " Figs. 622 1 inch = 1 foot.

In very large roofs a strut on the same principle as the last mentioned may be constructed by using 4-angle irons kept apart by cross-shaped distance pieces. These crosses are made smaller and smaller as they approach the ends of the strut, which is therefore shaped somewhat like a weaver's shuttle, being wide in the middle and tapering towards its extremities.

Tie and Tension Rods in large roofs are of circular rod iron, or flat bars, as already described for smaller roofs—and are secured in a similar manner. L iron tie rods are very convenient for connections (see Plate XVIII.)

Flat bars, both single and double (Fig. 620), are more common in large than in small roofs, and have the advantage of being less liable to sag than circular rods of the same tensile strength.

Steel tie rods have occasionally been used in combination with wrought-iron rafters, but as before stated the entire truss is now usually constructed of mild steel.

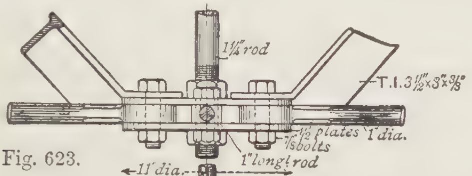


Fig. 623.

Detail at Centre

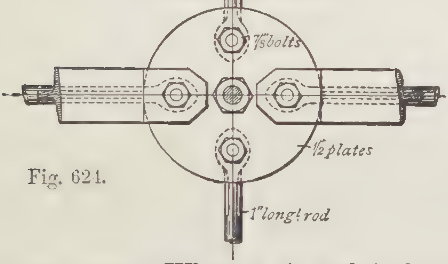


Fig. 624.

Joints in Tie Rod.—When a tie rod is long it is severed at the centre, sometimes at two or more points. The joints may in a round tie rod be formed as shown in Figs. 623, 624 (which are details of the joint at A, Fig. 638, Plate XII.), or as in Figs. 665, 666, Plate XV. When the tie rod is a T iron or flat bar a very simple joint may be made as in Fig. 625.

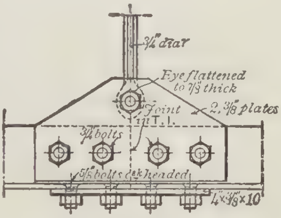


Fig. 625.

Handyside's Patent Couplings.—Plates XVI. and XVII. give several illustrations of joints patented by Messrs. Handyside of Derby for roofs in which steel tie rods are used. The ends of the rods to be connected instead of being forked are bolted to steel straps of the form shown in Fig. 681. This has the great advantage of avoiding eyes, forks, or heads, which would be more difficult to form on steel rods than on those of iron. Moreover

the joint is compact and neat in appearance, and each portion of the tie rod can be adjusted to the exact length required by merely turning it round.

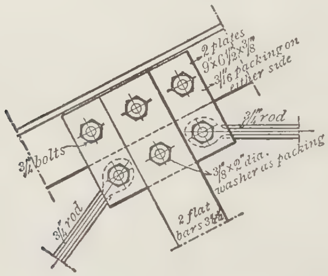
Coupling Boxes.—The tie rod should be so arranged with coupling boxes (see p. 286) or cottered joints that it can be altered in length in order to set up the roof when required.

In large roofs it is an advantage to arrange the tension rods in the same way, either with union screws—cottered joints—or with reverse screws at either end, so that by revolving the rod the screws turn opposite ways, and lengthen or shorten the rods.

These shackles, etc., are not shown in the small scale figures. They are often omitted in practice, the result being that the tension rods either become slack or undergo a greater stress than they are intended to bear.

Connections at Heads and Feet of Struts.—Several forms of these are shown in Figs. 620, 621, 622, 623, 624, also in

Fig. 626.



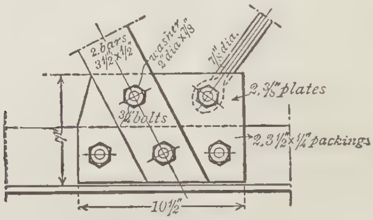


Fig. 627.

Plates XII. XIV. XV. XVI. XVII. XVIII. XIX. They require no explanation. Figs. 626, 627 show simple forms constructed with plates.

Suspending Rods for large roofs are similar in every respect to those described on p. 286, and nothing more need be said regarding them.

Shoes and Heads.—The lower extremities of principal rafters are sometimes secured in cast-iron shoes with cottered joints, as already explained on p. 282. Cast-iron heads are seldom used for large roofs.

Illustrations of cast-iron shoes are given on p. 285, also in Figs. 646, 647, 648, Plate XIII., and in Figs. 655, 656, 657, Plate XIV.

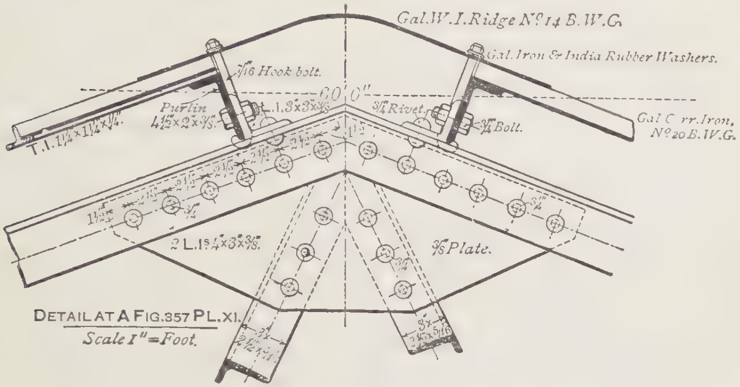


Fig. 628.

Simpler joints are formed by the use of flat wrought-iron plates, to which the parts to be connected are bolted or riveted. When

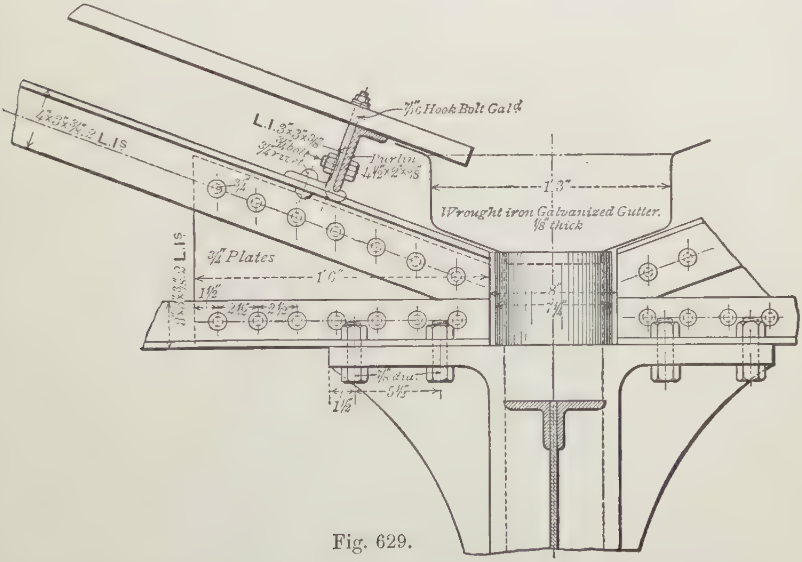


Fig. 629.

the principal rafter is of two angle irons one plate may be inserted between them, as in Figs. 628, 629, which are details of the joint A of the roof, Plate XVIII., and of Fig. 694, Plate XIX. When the principal rafter is of T iron then two plates may be used, one

on each side of the web, as in Fig. 664, Plate XV., and Figs. 677, 678, Plate XVII.

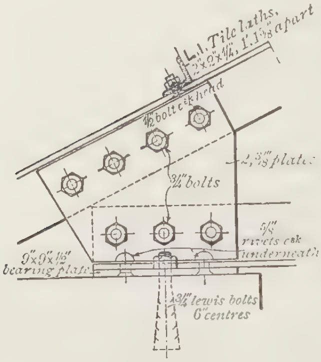


Fig. 630.

Fig. 630 is a simple joint with plates connecting the foot of the principal rafter with a tie of T iron.

Expansion and Contraction Arrangements.—Iron expands or contracts about $\frac{1}{150000}$ of its length for every degree on the Fahrenheit scale.

It is therefore important to make provision in all large roofs for the expansion and contraction caused by changes of temperature.

This is generally done by leaving one end of the truss free to move horizontally.

In roofs of great span the chair or saddle at the free end of the truss is supported on steel rollers, so that it can move outwards and inwards with ease under changes of dimension caused by the effects of temperature.

In smaller roofs the same object may be attained by supporting the shoe on a sheet of lead, and making the holes for the bolts which secure it, slots of an oblong form, so that the shoe can move slightly backward and forward on the lead.

It is better to fix the end from which the heaviest gales are most likely to blow.

"In countries liable to hurricanes extra precautions must be taken, and not only should the roof be strongly braced together by wind ties, but the entire structure should be well anchored to the ground. The latter precaution is especially necessary in buildings open at the sides or ends, and liable therefore to severe wind pressure below the roof."[1]

Fig. 631 shows the arrangement adopted to allow for expansion and con-

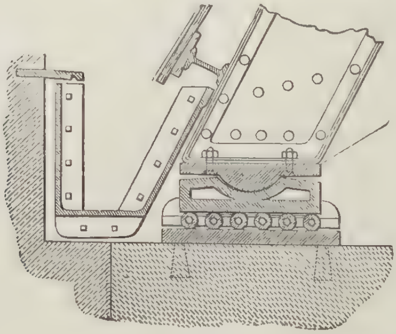


Fig. 631.

traction at the foot of a main principal of the bowstring type in a roof over a large railway station. The arrangement consists of a cast-iron bedplate

[1] *Works in Iron*, by Ewing Matheson.

attached to the foot of the principal, having a segmental knuckle or hinge bearing on another bedplate recessed to receive it, which in its turn is supported by a system of rollers resting upon a bedplate securely attached to a heavy stone template on the summit of the wall or pier. The rollers are turned, and all bearing surfaces of the bedplates machined. By these means any inequality of stress arising from distortion of the roof principal under wind pressure is mitigated, and the rollers are practically uniformly loaded. The motion of the rollers over the lower bedplate is intended (in theory at least) to take up the expansion or contraction of the principal under changes of temperature.

Attachment to Columns.—Iron roofs covering railway stations, sheds, etc., very frequently rest either one or both sides on the heads of iron columns.

The attachment of the foot of the rafter to the head of the column is effected in several different ways; one or two of which will now be described.

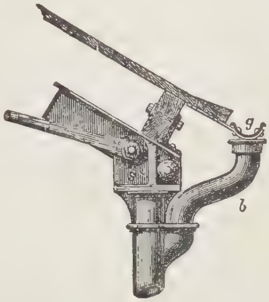


Fig. 632.

Fig. 632 shows the head of a column supporting a small roof. The shoe, *s*, which receives the foot of the rafter, is cast in one piece with the column. The swan-neck bend, *b*, receives the water from the gutter, *g*, and conveys it into the column, which acts as a down pipe.

Fig. 633 is a side elevation, and Fig. 634 is a front elevation,

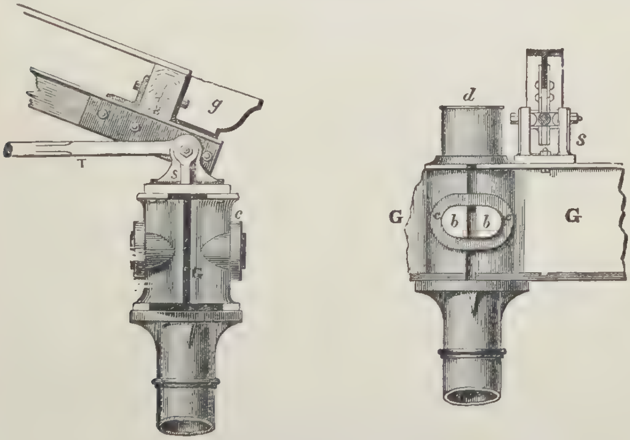


Fig. 633. Scale, ½ inch = 1 foot. Fig. 634.

showing the method by which the roof described in p. 304 is supported.

In this case the chair, *s*, is a distinct casting, and bolted on to the girder close to the head of the column.

The intervals between adjacent columns are spanned by cast-iron girders, G, the ends of which are swelled out and brought round so as to grasp the head of the column.

On the ends of these girders are cast burrs, *b*, and round these is a coupling link, *c c*, of wrought iron, so as to hold the girders together.

In this case the gutter, *g*, discharges through the socket *d*, down the interior of the column.[1]

Wind Ties are long rods passing from the foot of a principal rafter diagonally across three or four trusses, to which they are secured, until they reach the ridge; they are generally arranged so as to converge in pairs, as shown in Fig. 635, and should be furnished with union or cottered joints, so that they may be adjusted as to length: these joints are not shown in the figure. Details showing the connection of the wind ties to the rafter are given in Fig. 654, Plate XIV.

Such tie rods should be fixed to all large iron roofs, to secure

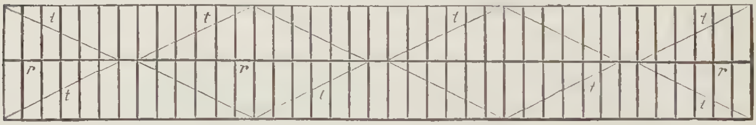


Fig. 635.

them against the effects of gales blowing at an inclination to the length of the roof.

They are hardly necessary when the gables of the building are of solid masonry, but in many cases, even when the roof is not hipped, the gable end is merely filled in with glass, and they are then required.

Lanterns and Ventilators.—The variety of forms of these is very great; one or two different kinds are shown in the accompanying illustrations.

In Fig. 613 a large ventilator is formed with vertical T iron

[1] The example given in Figs. 633 and 634 is characteristic of a type of construction in frequent use when cast-iron girders were in vogue. It is now, however, out of date. In present-day construction the cast-iron girder would be replaced by a mild-steel joist or lattice or plate girder, and the details of connection with the head of the column would be modified.

side standards, and covered with corrugated iron supported upon curved T iron rafters.

In Fig. 611 the ventilator has a central cast-iron standard in addition to T iron standards on each side, the latter being filled in with wooden louvres. The covering to the ventilator is the same as that of the roof, *i.e.* slating on boards fixed to angle irons filled in with wood.

Plate XIV. gives details of a lantern-skylight, flat skylight, and ridge ventilator.

Fig. 636 is an enlarged section of the lantern and ventilator surmounting the roof in Fig. 614.

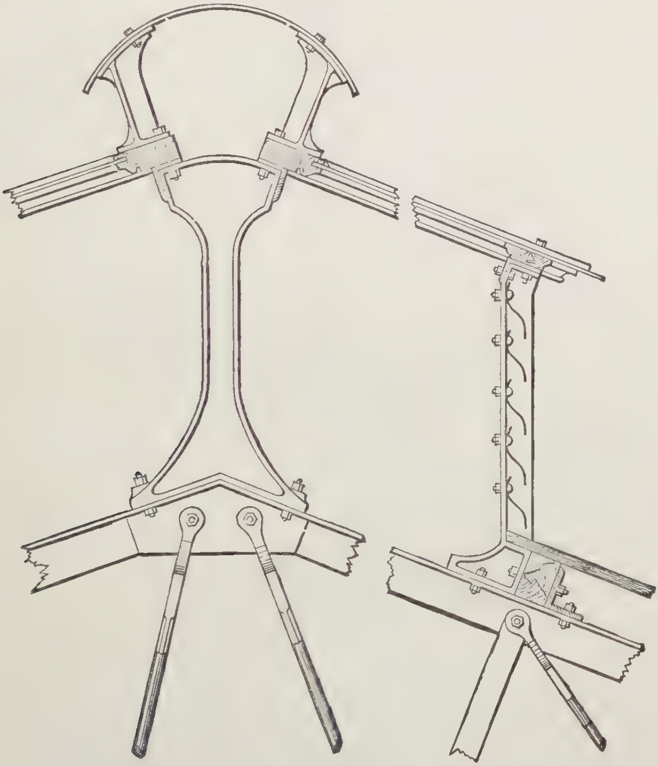


Fig. 636.
Scale, ½ inch = 1 foot.

The construction is evident from the figure, and requires but little explanation.

The skylight itself is supported by a central cast-iron standard bolted to the head, which receives the rafters, and has side

standards of the same material, with galvanised iron louvres. It is covered by an ordinary wooden skylight sash, having deep bars filled in with glass.

Surmounting the skylight is a ventilator open at the sides, which are formed by cast-iron standards, supporting a covering of corrugated iron bolted to flanges formed upon their upper extremities.

Coverings for Iron Roofs.—The coverings used for wooden roofs have already been described at p. 208, Chap. XII., and p. 216, Chap. XIII.

Most of these can be used for iron roofs, in some cases with slight modifications in the way of laying.

Slating.—Duchess or other large slates are very often used for iron roofs, and they may be laid either upon boards, or upon angle iron laths, as described in Chap. XIII.

Tiling of all kinds may also be used, laid upon laths in the same manner as slating.

Corrugated Iron may be used in the shape of an arch to form the roof itself, without supporting trusses, as mentioned at p. 273, or it may be arched and supported by curved angle or T irons; or it may be laid in sheets upon regular trusses of any form.

The sheets may be laid with the corrugations running either way, either horizontally or down the slope of the roof; the latter arrangement is much to be preferred.

The sheets are of course strongest in the direction of the length of the corrugation; the strength depends upon the depth of the corrugation, thickness of iron, etc.; and in this direction they may be left to span spaces of from 8 to 15 feet without support.

If the corrugations run up and down the slope of the roof, the sheets are supported upon purlins; if the corrugations are horizontal, the sheets rest upon the principals themselves, or when these are widely spaced, upon secondary rafters.

Zinc may be laid upon boarding with wooden rolls, as described at p. 210; or on the Italian system, as described at p. 213.

Lead is now very seldom used in iron roofs, having been almost entirely superseded by zinc.

Glass is a good deal used in large skylights,[1] which often form a considerable portion of the slope of the roof, and run nearly throughout its length.

[1] For glazing without putty see Part II.

It is also, in large roofs, extensively used upon the "*ridge-and-furrow*" system. This consists in forming small $\wedge$ roofs between the secondary rafters, which rest upon the purlins. The ridges of these small roofs generally run horizontally, and their slopes drain into gutters, lying along the upper flanges of the secondary rafters.

Contract Drawings of Iron Roofs.

Plates XII. to XIX. are reduced copies of part of the contract drawings for some roofs recently constructed.

There is no object in describing them in detail, but it should be mentioned that Plates XVIII. and XIX. are inserted by the kind permission of Sir Alexander Rendel, K.C.I.E., and the remaining plates by that of Messrs. Handyside and Co.

The student will derive more benefit by carefully studying these practical drawings of well-designed roofs than from representations of roofs drawn merely to illustrate the text.

TABLE OF SCANTLINGS OF IRON ROOFS[1] (from actual practice).

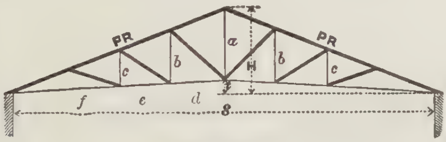


Fig. 637.

Rise, $H = \frac{s}{5}$. Rise of Tie Rod, $t = \frac{s}{45}$. Principals 6 feet 8 inches apart

Span, *s*.	Rafter, PR.	Struts, S.	King Bolt.	Queen Bolt.		Tie Rod.		
In feet.	T iron.	T iron.	*a*.	*b*.	*c*.	*d*.	*e*.	*f*.
	Inches.	Inches.						
20	$2\frac{1}{2} \times 2 \times \frac{3}{8}$	$2 \times 2 \times \frac{3}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	..	$\frac{5}{8}$	$\frac{3}{4}$	..
25	$2\frac{3}{4} \times 2\frac{1}{2} \times \frac{3}{8}$	$2 \times 2 \times \frac{3}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{7}{8}$	1	...
30	$2\frac{3}{4} \times 2\frac{1}{2} \times \frac{1}{2}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	1	$\frac{3}{4}$	$\frac{5}{8}$	1	$1\frac{1}{8}$	...
35	$3 \times 2\frac{3}{4} \times \frac{1}{2}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	1	$\frac{3}{4}$	$\frac{3}{4}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
40	$3\frac{1}{2} \times 3 \times \frac{1}{2}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
45	$4 \times 3\frac{1}{2} \times \frac{1}{2}$	$3 \times 3 \times \frac{1}{2}$	$1\frac{1}{4}$	1	$\frac{7}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
50	$4 \times 3\frac{1}{2} + \frac{5}{8}$	$3 \times 3 \times \frac{5}{8}$	$1\frac{3}{4}$	1	$\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$
55	$5 \times 4\frac{1}{2} \times \frac{5}{8}$	$4 \times 4 \times \frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{8}$	1	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$
60	$5 \times 4\frac{1}{2} \times \frac{3}{4}$	$4 \times 4 \times \frac{5}{8}$	$1\frac{3}{8}$	$1\frac{1}{8}$	1	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$

[1] From Molesworth's *Pocket Book*.

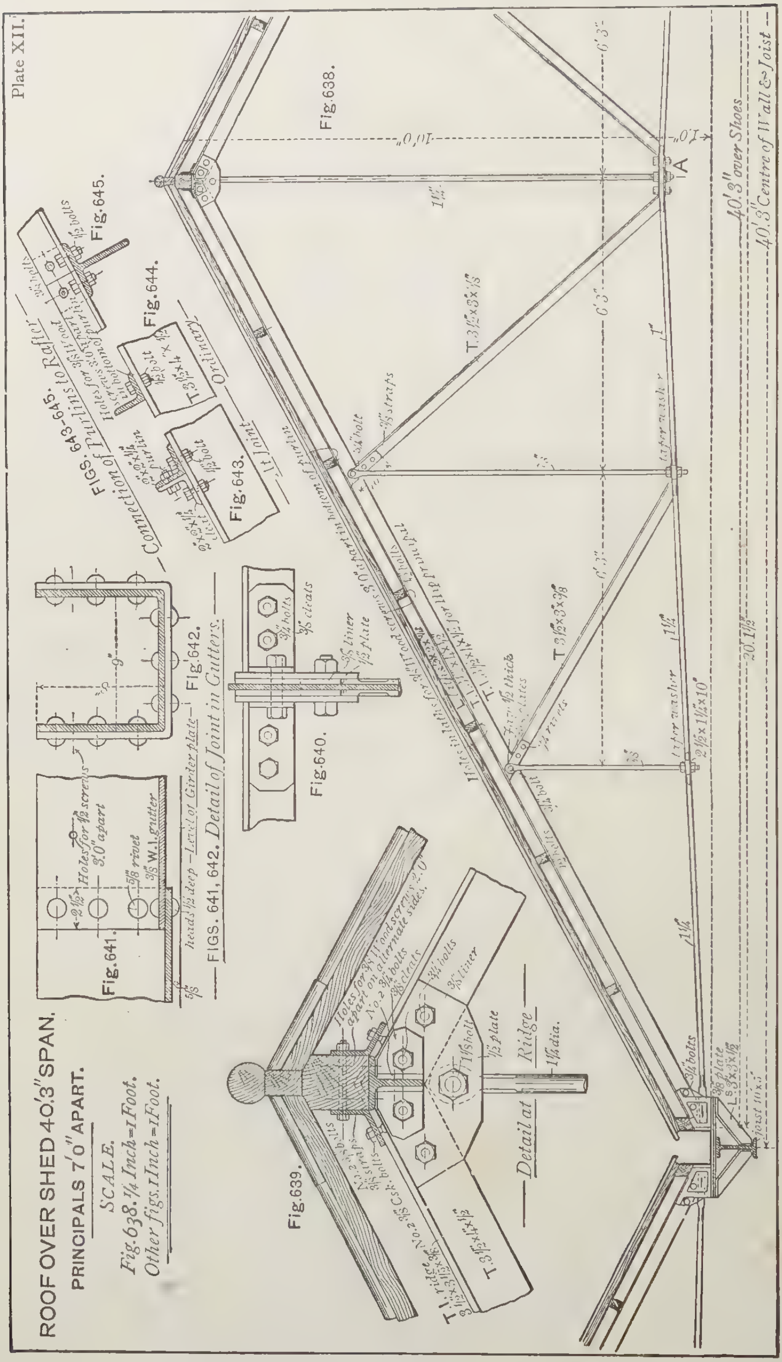


Plate XII.
ROOF OVER SHED 40'3" SPAN.
PRINCIPALS 7'0" APART.
SCALE.
Fig. 638. 1/4 Inch = 1 Foot.
Other figs. 1 Inch = 1 Foot.
Fig. 638.
Fig. 639.
Detail at Ridge
Fig. 640.
Fig. 641.
Fig. 642.
FIGS. 641, 642. Detail of Joint in Gutters.
Level of Girder plate
Fig. 643.
Fig. 644.
Fig. 645.
FIGS. 643-645. Connection of Purlins to Rafter
Ordinary
Lt Joint
40'3" over Shoes
40'3" Centre of Wall & Joist
A

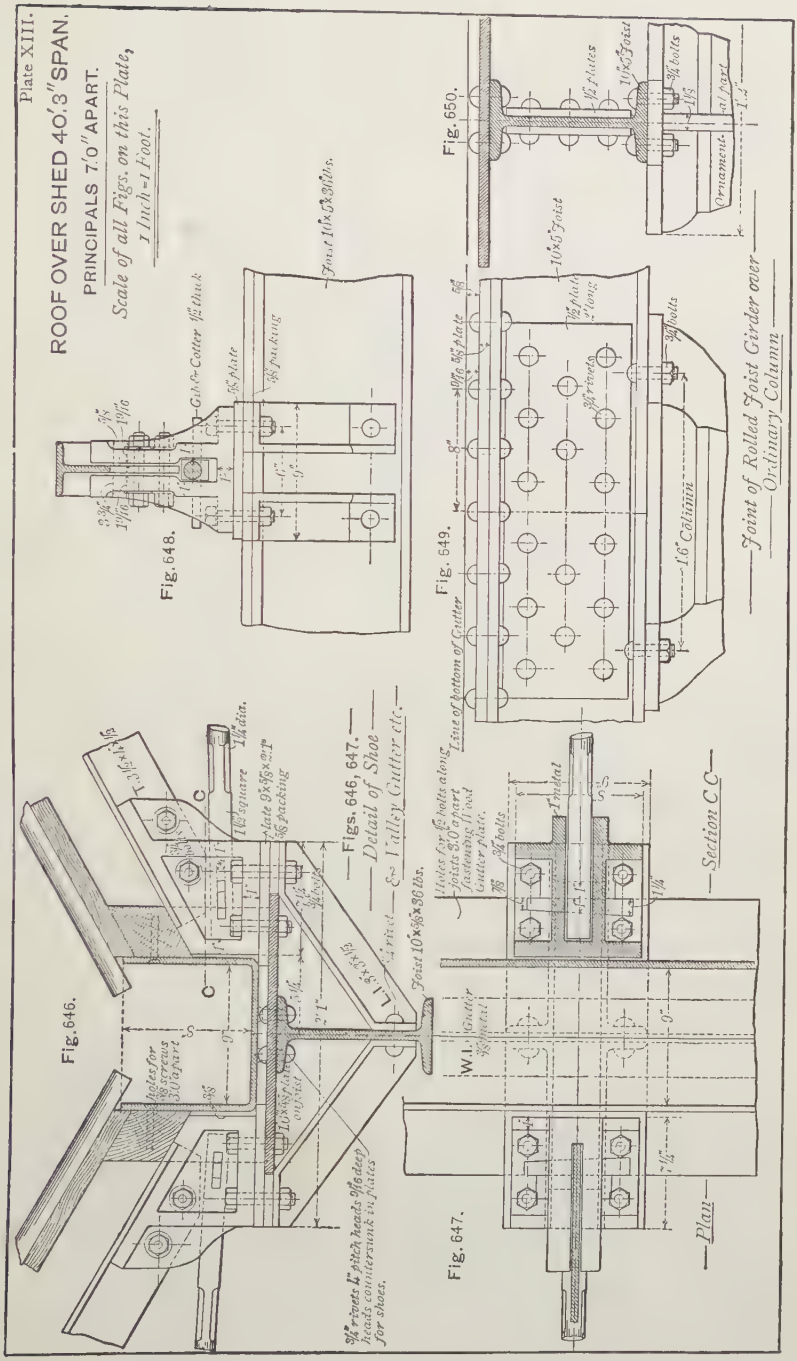


Plate XIII.
ROOF OVER SHED 40'.3" SPAN.
PRINCIPALS 7'.0" APART.
Scale of all Figs. on this Plate,
1 Inch = 1 Foot.
Fig. 646.
Fig. 647.
Figs. 646, 647.
Detail of Shoe
& Valley Gutter etc.
Section CC
Plan
Fig. 648.
Fig. 649.
Fig. 650.
Joint of Rolled Joist Girder over
Ordinary Column

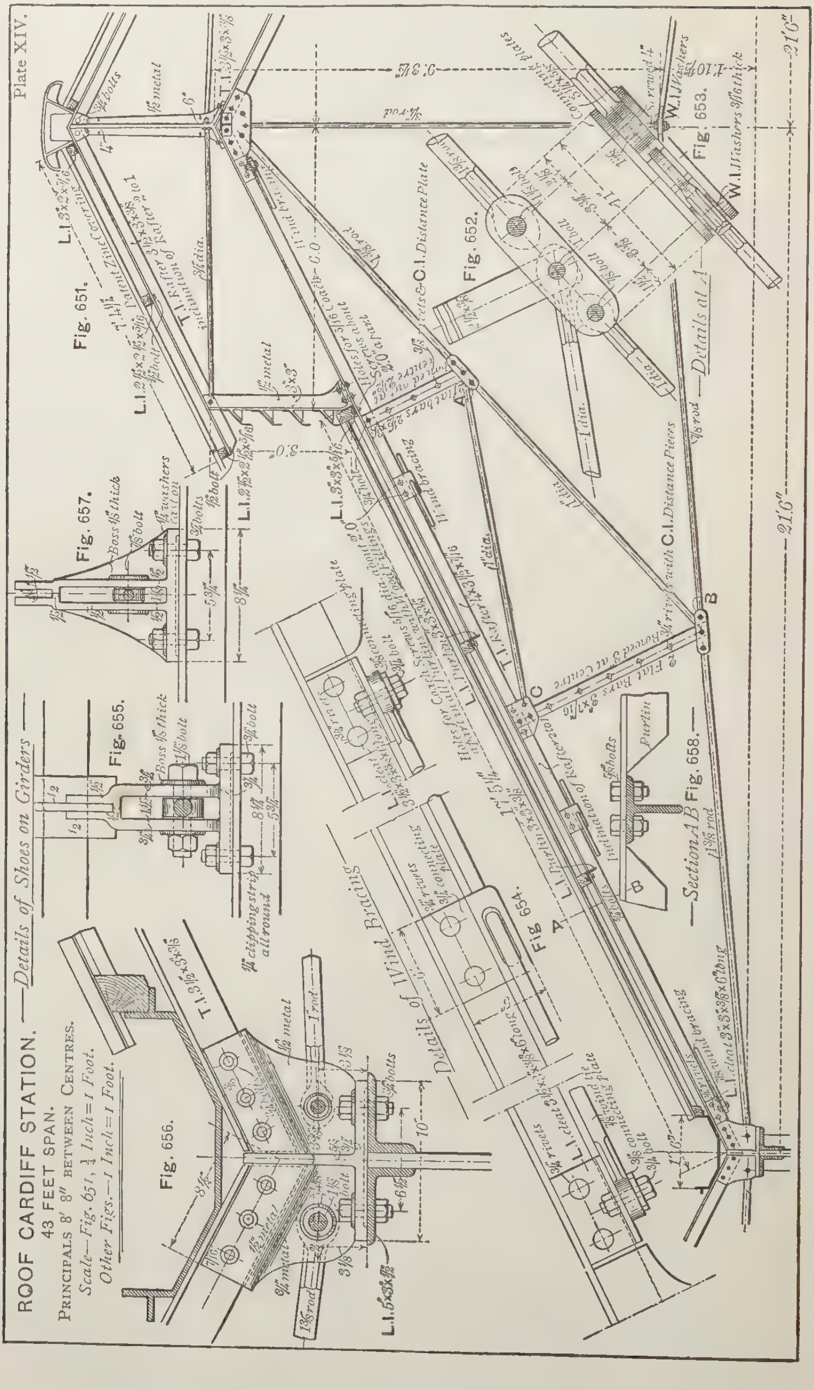


Plate XIV.
ROOF CARDIFF STATION.
43 FEET SPAN.
PRINCIPALS 8' 8" BETWEEN CENTRES.
Scale—Fig. 651, ¼ Inch=1 Foot.
Other Figs.—1 Inch=1 Foot.
Fig. 651.
Fig. 652.
Fig. 653.
Fig. 654.
Fig. 655.
Fig. 656.
Fig. 657.
Fig. 658.
—Details of Shoes on Girders—
—Details of Wind Bracing—
—Details at A—
—Section AB—
Patent Zinc Covering
Wind bracing
C.I. Distance Piers
C.I. Distante Plate
W.I. Washers
Purlin
21'6"

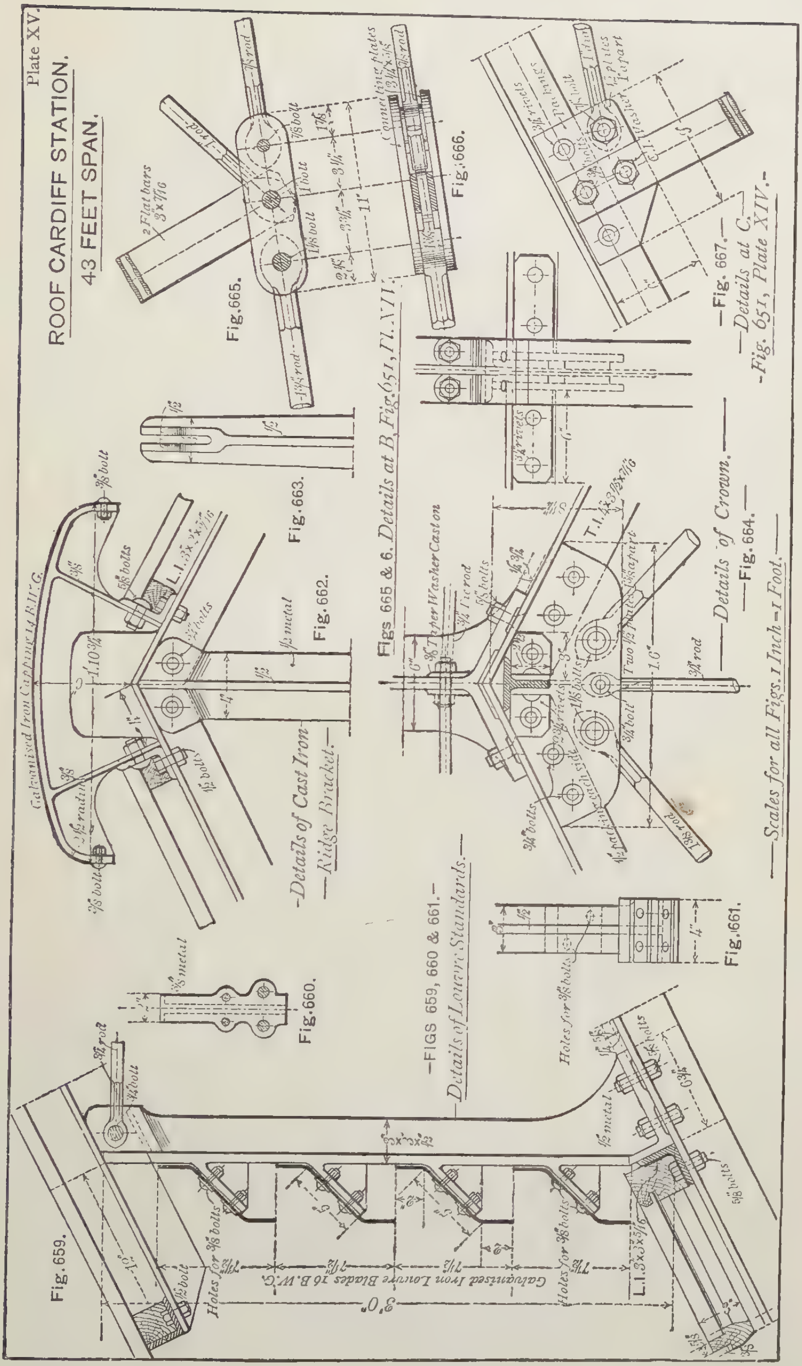
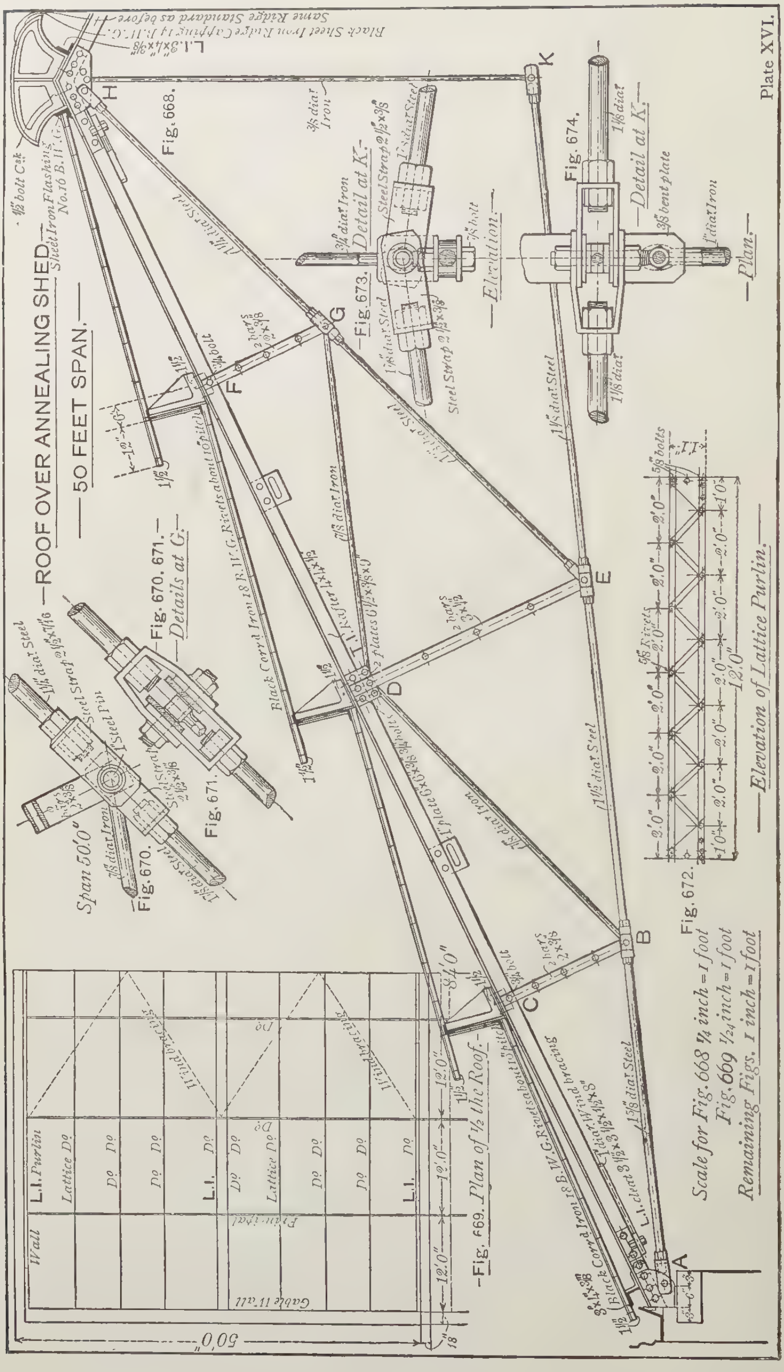


Plate XV.
ROOF CARDIFF STATION.
43 FEET SPAN.
Fig. 665.
Fig. 666.
Figs 665 & 6. Details at B, Fig. 651, Pl. XIV.
Fig. 667.
Details at C.
Fig. 651, Plate XIV.
Fig. 663.
Fig. 662.
Details of Cast Iron Ridge Bracket.
Galvanised Iron Capping 14 B.W.G.
Fig. 664.
Details of Crown.
Scales for all Figs. 1 Inch = 1 Foot.
FIGS 659, 660 & 661.
Details of Louvre Standards.
Fig. 660.
Fig. 661.
Fig. 659.
Galvanised Iron Louvre Blades 16 B.W.G.



ROOF OVER ANNEALING SHED.
50 FEET SPAN.
Span 50′0″
Fig. 668.
Fig. 669. Plan of ½ the Roof.
Fig. 670.
Fig. 671.
Fig. 670. 671. Details at G.
Fig. 672.
Elevation of Lattice Purlin.
Fig. 673. Detail at K. Elevation.
Fig. 674. Detail at K. Plan.
Scale for Fig. 668 ¼ inch = 1 foot
Fig. 669 1/24 inch = 1 foot
Remaining Figs. 1 inch = 1 foot
Plate XVI.

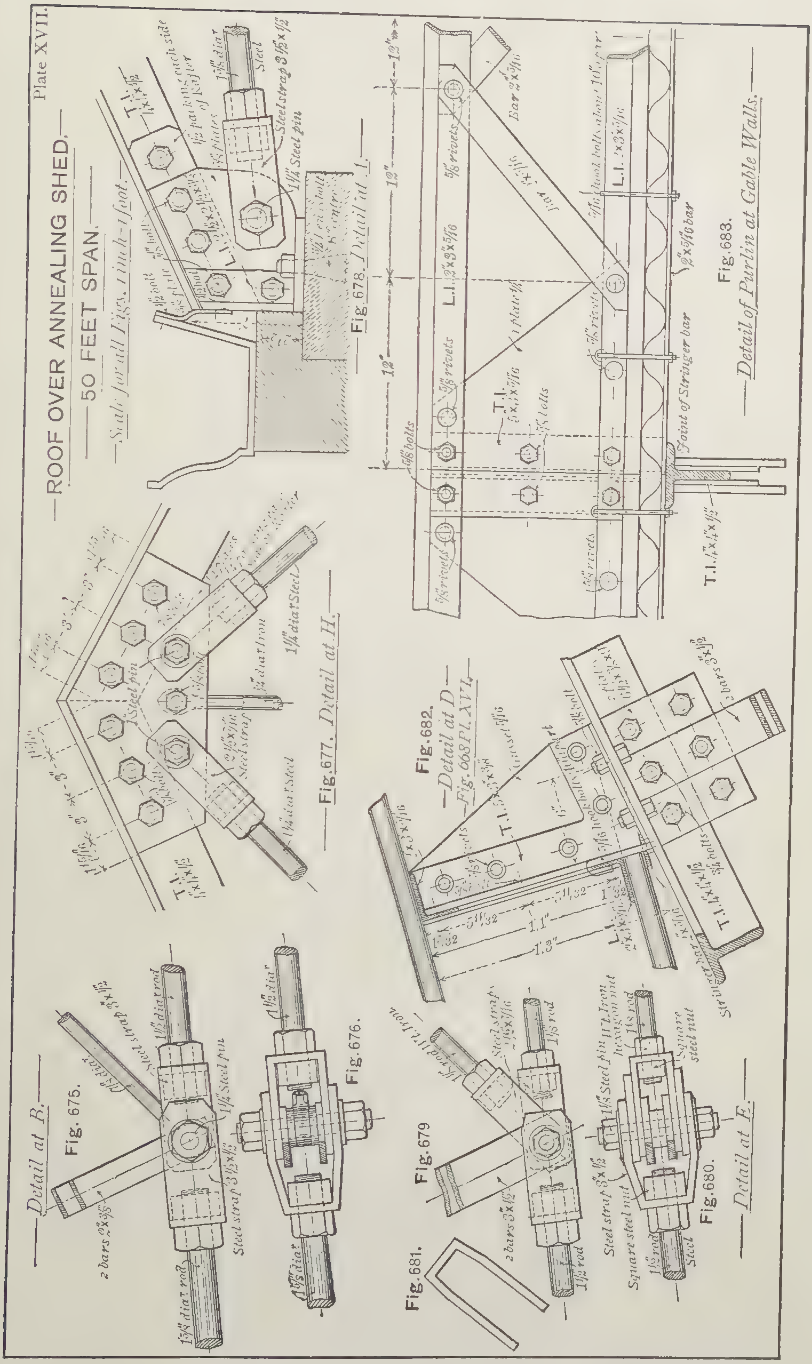
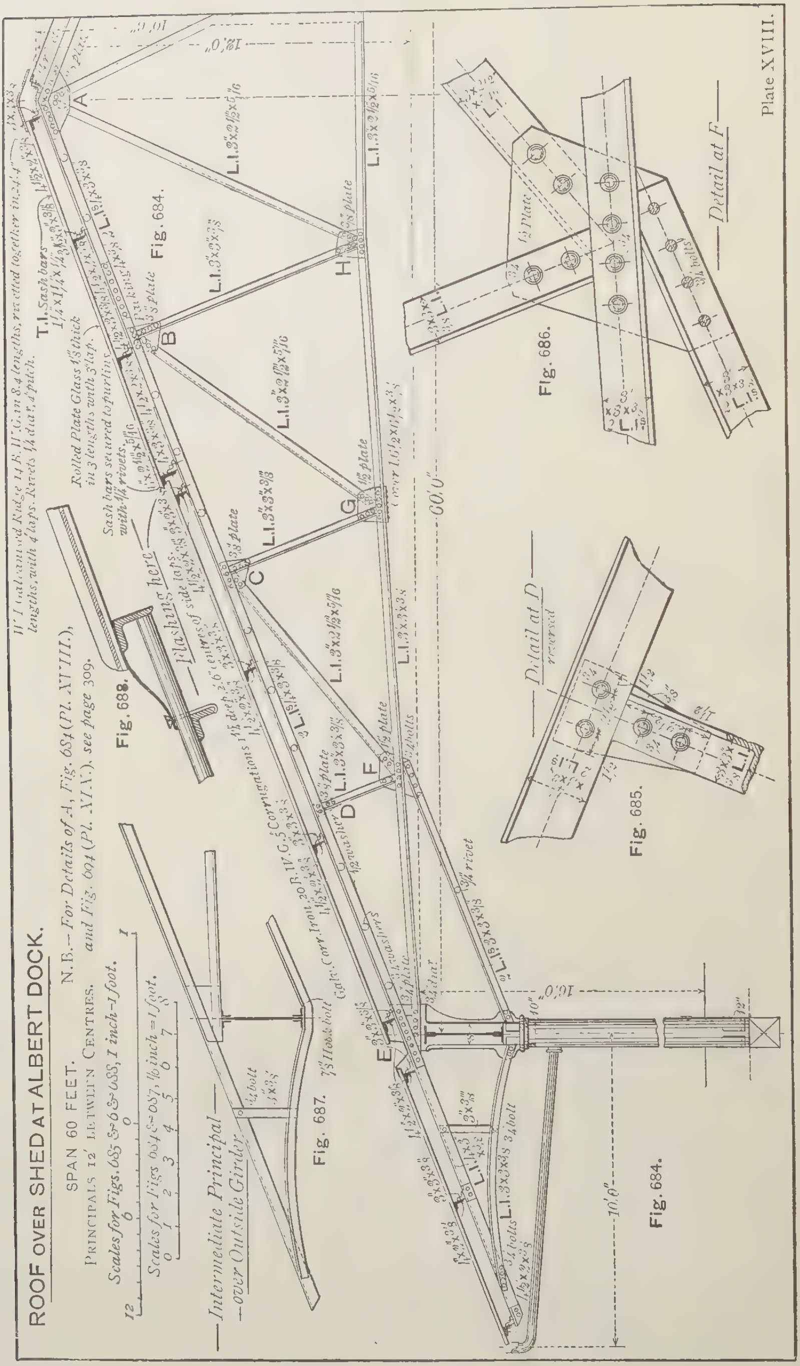


Plate XVII.
ROOF OVER ANNEALING SHED.
50 FEET SPAN.
Scale for all Figs. 1 inch = 1 foot.
Fig. 678. Detail at A.
Fig. 683.
Detail of Purlin at Gable Walls.
Fig. 677. Detail at H.
Fig. 682.
Detail at D
Fig. 668 Pl. XVI.
Detail at B.
Fig. 675.
Fig. 676.
Fig. 679
Fig. 681.
Fig. 680.
Detail at E.


ROOF OVER SHED AT ALBERT DOCK.
SPAN 60 FEET.
PRINCIPALS 12' BETWEEN CENTRES.
N.B.—For Details of A, Fig. 684 (Pl. XVIII), and Fig. 604 (Pl. XIX), see page 309.
Intermediate Principal over Outside Girder
Fig. 684.
Fig. 685.
Fig. 686.
Fig. 687.
Fig. 688.
Detail at D reversed
Detail at F
Flashing here
60'0"
10'0"
Plate XVIII.

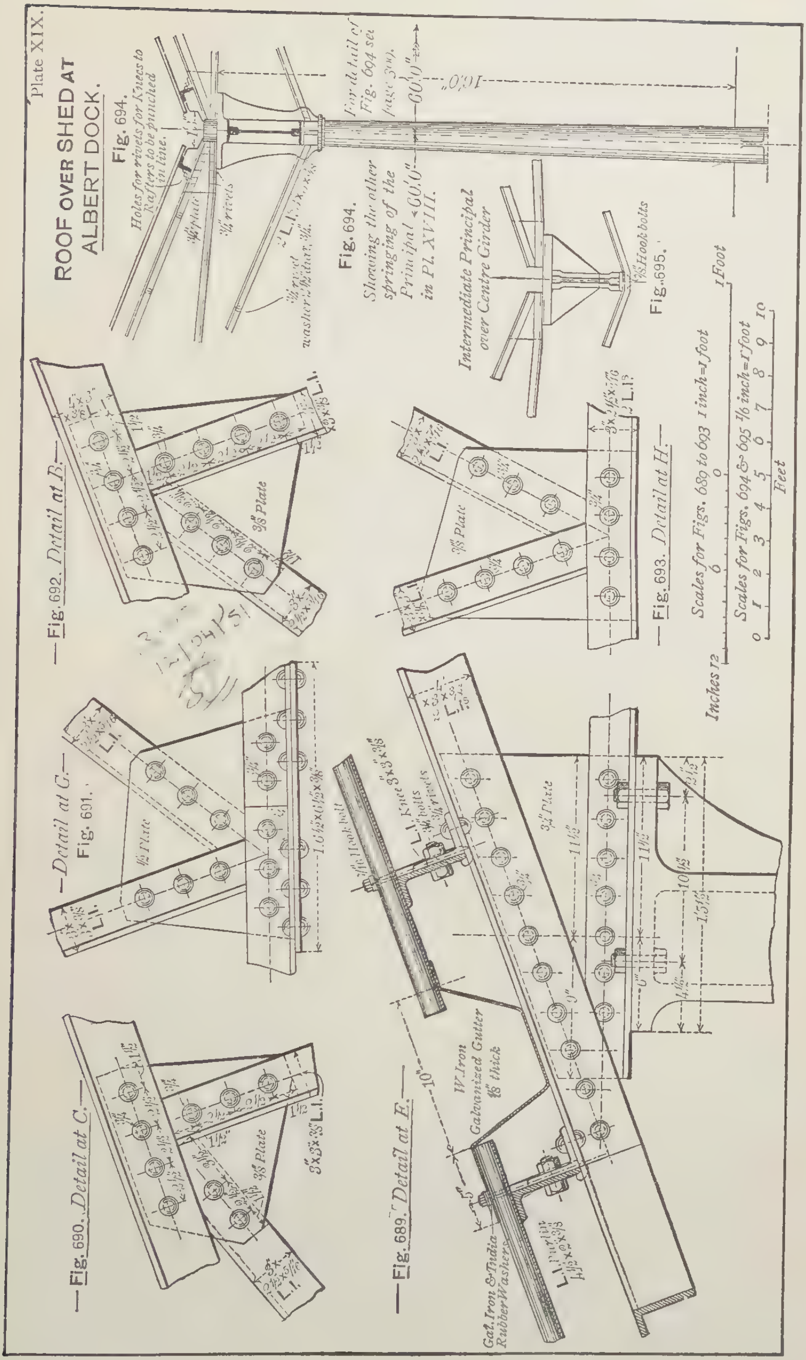


Plate XIX.
ROOF OVER SHED AT ALBERT DOCK.
Fig. 694.
Fig. 694. Showing the other springing of the Principal 60'0" in Pl. XVIII.
Intermediate Principal over Centre Girder
Fig. 695.
Fig. 692. Detail at B.
Fig. 693. Detail at H.
Detail at G. Fig. 691.
Fig. 690. Detail at C.
Fig. 689. Detail at E.
Scales for Figs. 689 to 693 1 inch=1 foot
Scales for Figs. 694 & 695 1/6 inch=1 foot
Inches 12
Feet

APPENDIX.

EXAMINATIONS IN SCIENCE, SOUTH KENSINGTON.
SUBJECT III.—BUILDING CONSTRUCTION.

General Instructions (1903).

If the rules are not attended to, the paper will be cancelled.

Immediately before the Examination commences, the following
Regulations *are* to be read to the Candidates.

Before commencing your work, you are required to fill up the numbered slip which is attached to the blank examination paper.

You may not have with you any books, notes,[1] or scribbling paper.

You are not allowed to write or make any marks upon your paper of questions, or to take it away before the close of the examination.

You must not, under any circumstances whatever, speak to or communicate with one another, and no explanation of the subject of examination may be asked or given.

You must remain seated until your papers have been collected, and then quietly leave the examination room. None of you will be permitted to leave before the expiration of one hour from the commencement of the examination, and no one can be readmitted after having once left the room.

Your papers, unless previously given up, will all be collected at ——.

If any of you break any of these rules, or use any unfair means, you will be expelled, and your paper cancelled.

Before commencing your work, you must carefully read the following instructions :—

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Note.—*A candidate in any subject who applied for examination in the Elementary Stage was required to confine himself to that stage. A candidate who had not applied to take the Elementary Stage was allowed to take the Advanced Stage, or, if eligible, Honours, Part I. or II., but was required to confine himself to one of them.*

[1] In certain practical examinations candidates were allowed the use of books, notes, etc.—*see* special instructions preceding the papers of questions in those subjects.

1901.

Elementary Stage.

INSTRUCTIONS.

Read the General Instructions.

You are permitted to answer only *seven* questions.

1. Why is a brick made so that its breadth is less than half its length? Can you explain any advantage in "perforating" bricks? What are gauged arches? (12.)
2. Draw, to the scale of $\frac{1}{16}$, the plans of two courses of a brick pillar in English bond: the pillar to be square in section, four bricks in the side. To what height could you *safely* build a pillar of this section, assuming the safe load on a course of bricks to be 8 tons per square foot and taking the weight of a cubic foot of brickwork at 120 lbs.,—neglecting wind pressure? (12.)
3. What are:—a skew arch; a skewback; a pillar; an abutment; a column; weathering of a window sill; weathering of stone; voussoirs; chamfer; plinth? (12.)

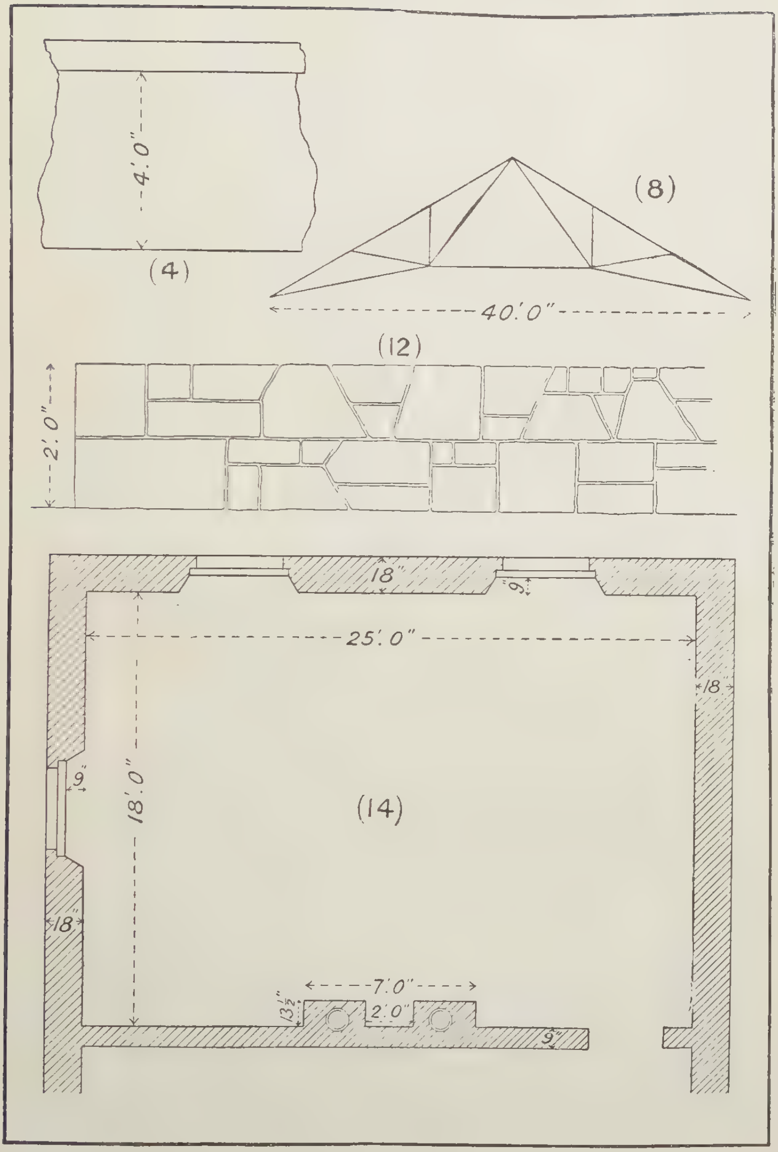
*4. A rubble wall with half-round concrete coping: draw it to the scale of $\frac{1}{16}$. Showing the stones and mortar. (12.)

5. Show three soakers with cover flashing in position against a brick wall,—slates 24″ long. Show clearly to the scale of $\frac{1}{4}$ all details, with such drawings and sketches, accompanied by explanations and dimensions, as you think sufficient. (12.)
6. Draw or sketch, to the scale of $\frac{1}{4}$:—
   (1) A tenon and housed joint, mortised piece 4″ × 4″, tenoned piece 3″ × 4″.
   (2) A tusk-tenoned joint, 9″ × 3″ timbers.
   (3) A dovetailed notch, timbers $4\frac{1}{2}$″ × 3″. (12.)
7. Draw or sketch, to the scale of $\frac{1}{8}$, the top and bottom of a king post showing attachments of principal rafters and of the struts and tie-beam, and showing ironwork:—rafters 8″ × 4″, shank of king post 6″ × 4″, struts 4″ × 4″, tie-beam 12″ × 4″. (12.)

*8. A skeleton drawing of an iron roof truss. The rafters are formed of L irons. Draw, to the scale of $\frac{1}{2}$, the joint at the apex. Repeat the diagram on your paper, and putting reference numbers to the different members, sketch cross-sections of them. (14.)

9. Draw or sketch, to the scale of $\frac{1}{4}$, a cross-section showing bottom rail of sash, wood sill of window frame, stone sill, and window back; showing elbow. The window back is 2 feet high and the wall of the recess is 10 inches thick. (14.)
10. Draw or sketch, to the scale of $\frac{1}{8}$, cross-section of eave extending 4 feet up the roof showing slates resting over a cut stone eave course: the wall is 18″ thick, rafters 5″ deep, without roof trusses,—ceiling joists at wall plates; slates 20″ long. Explain fully. (14.)
11. Draw, to the scale of $\frac{1}{16}$, the inside elevation of a ledged and braced door, and door frame; the door is 7′ × 3′. Show hinges, latch, stock lock; sketch cross-section showing jambs (wall $1\frac{1}{2}$ bricks thick). (14.)

1901.



*12. Two courses of masonry: how would you describe it? Sketch these two courses on your paper, and put reference numbers on the stones of the top course showing the order in which you think a mason would set them, giving reasons. (14.)

13. Draw, to the scale of $\frac{1}{8}$, elevation of a double casement or French window $6' \times 3'\ 6''$: draw cross-section of bottom bar of window and sill of frame; sketch hinges and fastening bolt. What is this kind of bolt called? (15.)

*14. A floor, of fir timber, joists lathed and plastered below to form ceiling of lower room. Draw plan, to the scale of $\frac{1}{48}$, showing by single lines complete joisting, figure scantlings. Draw, to the scale of $\frac{1}{8}$, cross-section through hearth reaching above camber-bar of fireplace. Show details of bearing of joists and of trimmer. (15.)

1902.

Elementary Stage.

INSTRUCTIONS.

In the Elementary and Advanced Stages drawings must be made on the single sheet of drawing paper supplied, beginning on the side marked with your distinguishing number, which must face you at the right-hand top corner. *Sketches* may be made by hand on the squared paper attached to the drawing paper. Additional foolscap will, if necessary, be supplied to you by the Superintendent.

Answers in writing must be as short and clearly stated as possible, and the references to drawings and sketches must be made absolutely clear by letters or numbers.

Questions marked (*) have accompanying diagrams.

The examination in this subject lasts for four hours.

You are permitted to answer only *seven* questions.

*1. Sketch this tool upon your paper, showing the pick better placed, and explain why you alter it. For what is this tool used? (12.)

2. What are:—Reveals, Jambs, Collar braces (Collar beams), Battens, Studs, Deals, Planks, Perpends, Screeds, Kingcloser? (12.)

*3. The figure shows in skeleton a bracket used by builders for pointing brickwork or for outside plastering: sketch the bracket so that an exact drawing could be made from your sketch (marking dimensions). Show clearly how its parts are connected (the parts being of red deal): show how it is supported when hung against a wall. (12.)

*4. What is the name of the bracket of the previous question? If we assume that it carries a uniformly distributed load of 8 cwt. on *AB*, so that we may imagine a downward force of 4 cwt. at *A*, what kind of stress is in *AC*, and what is its amount? (12.)

5. Given sand, lime, and hair, as delivered at the building, describe in detail how you would prepare "*coarse stuff*" for plastering—you are not supposed to have a mortar mill. (12.)

6. Sketch neatly to the scale of about $\frac{1}{6}$ a slate of the dimensions $24'' \times 12''$ dressed and holed: the lap is $4''$. What are the dimensions of the "weather" (or margin) of this slate? What is the distance from the hole to the tail? (12.)

*7. What is the name of the lock shown? Describe how you would fix it to a door. Explain and illustrate by sketches the mechanism of a common single tumbler lock. What are the "*wards*"? (12.)

*8. The sketch shows a door frame for an outside door: it is set upon door-blocks and the brick walls are being built to it.

Draw carefully to the scale of $\frac{1}{12}$ an elevation of the door frame, step, sill, and brickwork (showing the joints by double lines to the left of the door for, say, three bricks from the door): show temporary bracing: describe how you would stay the door frame temporarily. Draw, to the scale of $\frac{1}{4}$, cross-section of frame at AB, showing the plan of top course of brickwork, and a short piece of vertical section at C, showing the connection with the door block. (14.)

9. Sketch to the scale of $\frac{1}{12}$ a sample of snecked rubble masonry face (say about $4' \times 4'$). Show the mortar joints with double lines.

Sketch also the top of the sample, as a plan, showing how you bond the wall across. (14.)

10. A brick wall, 21 feet high (measured from the soil on which it rests) $13\frac{3}{4}''$ thick, carries a load of 1 ton per foot run on its top. Say what is the approximate weight of a cubic foot of brickwork. Draw, to the scale of $\frac{1}{24}$, a cross-section of the footings on the assumption that the soil is not to be stressed to a greater amount than 1 ton per square foot. (14.)

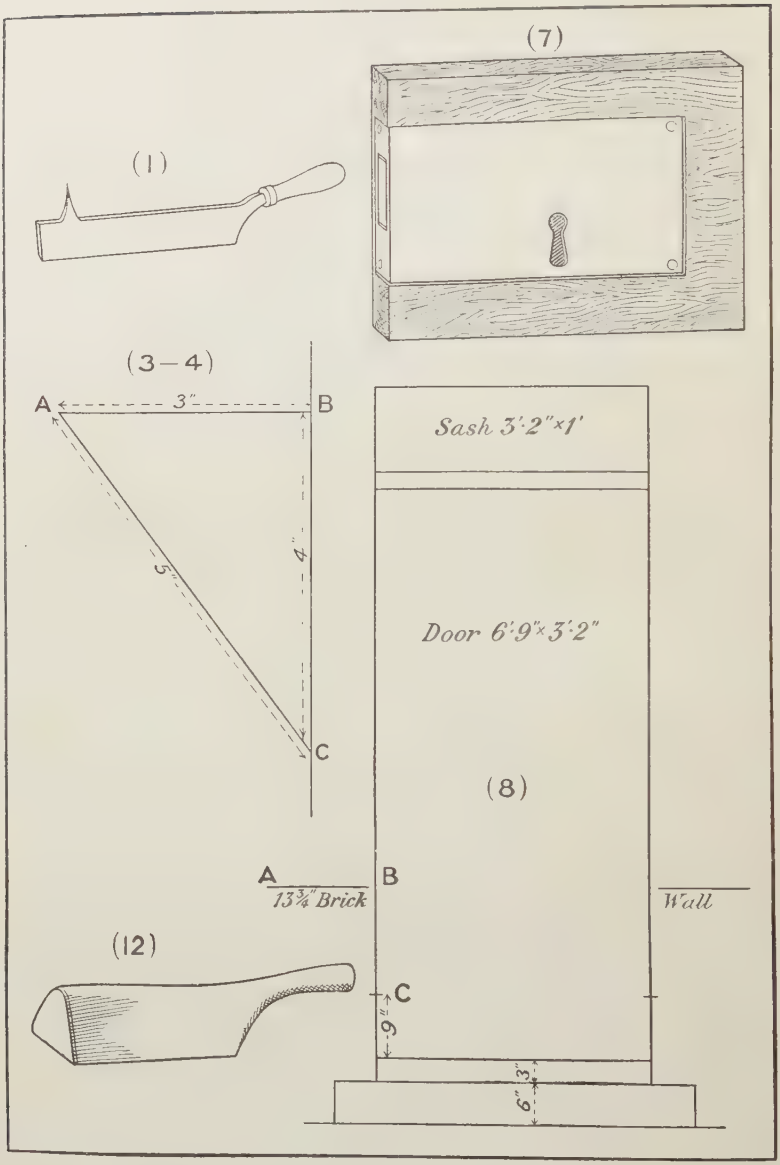
11. Describe exactly the laying of batten width tongued and grooved common Baltic flooring; how would you manage when the floor has been finished so far that there is no longer room for the cramps between the wall and finished floor? Sketch the usual flooring nail. What is it called? Where do you drive the nails? Sketch a cross-section of a heading joint. (14.)

*12. For what purpose is this tool used? You have to cover a right circular cone with 6 lbs. lead. The cone is $3'$ in diameter at the base, and it is $2'$ high. Assuming that the joints are butted, what is the weight of the lead? Such a cover being made, if a straight cut is made from the apex to the circumference of the base, the cover may be made to lie flat; draw to the scale of $\frac{1}{12}$ its outline when thus flattened. (14.)

13. What is bond in brickwork? When you say that a certain wall is built in Flemish bond, to what do you refer? You have to build a $1\frac{1}{2}$ brick wall, showing Flemish bond in *one face*—the appearance of the other face is of no consequence as it is to be plastered. *No bats are allowed.* Sketch the plan of a course, say 5 bricks long, in full lines and show the joints of the course below in dotted lines. (15.)

14. Describe carefully the work of laying a kitchen floor with $6'' \times 6''$ tiles, $\frac{1}{2}''$ thick, in two colours. The floor is $14' \times 13'$: how many tiles ought to be *ordered* for the work? (15.)

1902.



1903.

INSTRUCTIONS.

In the Elementary and Advanced Stages drawings must be made on the single sheet of drawing paper supplied, beginning on the side marked with your distinguishing number, which must face you at the right-hand top corner. *Sketches* may be made by hand on the squared paper attached to the drawing paper. Additional foolscap will, if necessary, be supplied to you by the Superintendents.

The *tracing* is to be drawn on the piece of tracing paper attached to the drawing paper.

Answers in writing must be as short and clearly stated as possible, and the references to drawings and sketches must be made absolutely clear by letters or numbers.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Questions marked (*) have accompanying diagrams.

The examination in this subject lasts for four hours.

Elementary Stage.

You are permitted to answer only seven questions.

*1. For what work is this tool used? Describe how the workman holds it when he uses it for ordinary work. (12.)

2. What are :—meeting-rail, muntin, tread, riser, going, lacing course, quirked ogee, coarse stuff, gauged stuff, droved work, rusticated? (Full marks will be given for *nine* correct definitions.) (12.)

*3. In a certain town electric wires are borne on brackets, like that shown: given the weight at A as being 40 lbs., assuming that this pressure may be transferred to the point B where the bracket bears against the slate, as shown, and assuming that the directions of the reaction and of the third force are as shown; what is the amount of the reaction in lbs.? (15.)

*4. Make a tracing, in ink, of this drawing and of the writing and figures. (The Indian ink should be sufficiently thick to give opaque lines, suitable for photographic printing; the lines should be well defined, uniform in breadth, having firm unbroken edges; and they should neither stop short of nor go beyond the proper points.) (15.)

5. Sketch (approximately), to the scale of $\frac{1}{2}$, a good strong thumb latch for a door; also the keeper, or catch, to be fastened to the door frame. Describe what you consider to be important points in a good latch, such as you sketch. (12.)

6. (*a*) What is a bib-cock? (*b*) Describe how a "wiped-joint" is made. (12.)

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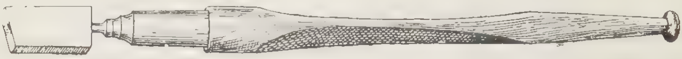

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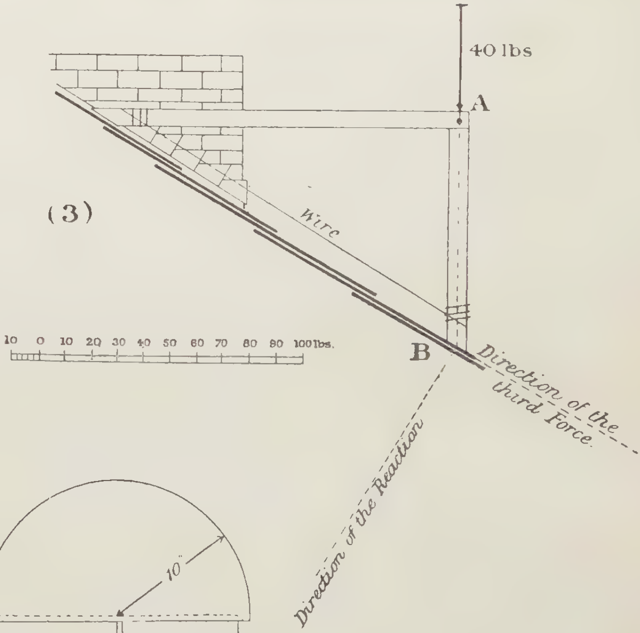

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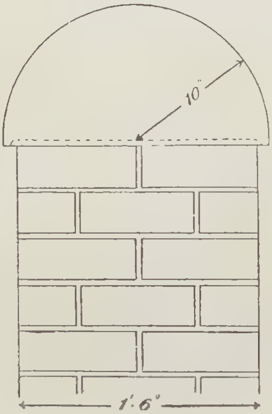

(4)

Elevation.

7. A rectangular rain-water tank weighs 300 lbs., it is $6' \times 4'$ and it is 2′ 6″ deep (internal dimensions), it is supported with its bottom horizontal. Owing to a stoppage of the overflow pipe, it is filled with water. (*a*) What is the pressure of the water, per square foot, on the bottom of the tank? (*b*) What is the weight of the tank and water? (*c*) How many gallons of water does the tank contain? (14.)
8. The slates on a roof are $24'' \times 12''$, an average slate weighs 7 lbs., the slates are laid with a lap of 4 inches; what is the weight of slates which cover an average square of roof? (14.)
9. Draw, to the scale of $\frac{1}{12}$, the elevation of a casement window (not a *pivoted* sash) $4' \times 2'$ 6″ (sash size); a single sash in 4 panes; show reveals and stone sill; sketch, approximately to the scale of $\frac{1}{4}$, the essential details of the hinges and fastener. (14.)
10. Sketch, to the scale of $\frac{1}{12}$, the face (elevation) of a completed course of rubble masonry (the course being, say, 15″ deep); sketch on top of this completed course portions of a second course in process of building; explain why the stones shown—of the second course—are placed where you sketch them. How does the mason keep his work truly in line? How does he use his plumb-rule in rock-faced work? (14.)
11. A plasterer is laying on the first coat of coarse stuff on lathed work and you see him driving the trowel at right angles to the direction of the laths; this is wrong, can you explain why it is wrong? (12.)
12. Sketch, to the scale of $\frac{1}{8}$ (approximately), a fireplace—grate, oven, and boiler—suitable for the kitchen or living-room of an artisan's cottage; explain the setting and flues. (14.)
13. Describe how you would prepare (from materials in the usual commercial conditions) a pot of light-coloured paint for fourth coating, inside work; give a name to the shade of colour you produce. (12.)
14. Draw plans of two successive courses of a half brick built chimney stack of three flues (scale $\frac{1}{12}$); show mortar joints as double lines, show pargeting. (12.)

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